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SEWERAGE SYSTEM MONITORING AND REMOTE CONTROL

Detroit Metro Water Department

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May 1975

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16. ABSTRACT

This publication is the final report of a demonstration project to apply sewer system monitoring and remote control techniques to reduce pollution of receiving waters from combined sewer overflows and storm wastewater pumping. The monitoring system includes telemetering rain gages, sewer level sensors and overflow sensors and a central computer and data logging facility. Wastewater pump stations and certain key regulators were remotely controlled to allow in-system storage. Remotely controlled sluice gates were installed in a sewer to study the feasibility of using dry weather flow to flush sewers. The report includes a detailed discussion and evaluation of the monitoring and remote control equipment, installation details, the concept of in-system storage, and the operation of the system based on an 18-month study period. Detroit has found that many of the larger sewers are not used to capacity during storms. Utilization of system monitoring and remote control techniques has resulted in a significant reduction in the volume of combined sewer overflows and storm wastewater pumping as well as reduced operation and maintenance costs. Results of a combined sewer sampling program are being used to establish priorities for future system modifications.

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SEWERAGE SYSTEM MONITORING AND REMOTE CONTROL

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Project No. 11020 FAX
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NATIONAL ENVIRONMENTAL RESEARCH CENTER
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U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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The National Environmental Research Center -- Cincinnati has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

Various means to abate the contamination of our waterways due to combined sewer overflows are currently being investigated by many researchers. In this report, the application of sewer monitoring and remote control techniques has been investigated as a means of reducing the frequency and duration of combined sewer overflows.

A. W. Breidenbach, Ph.D.
Director
National Environment
Research Center, Cincinnati

ABSTRACT

Sewer system monitoring and remote control techniques were used to reduce pollution of receiving waters due to combined sewer overflows and storm wastewater pumping from the City of Detroit's combined sewer system. The monitoring system includes telemetering rain gages, sewer level sensors and overflow sensors and a central computer and data logging facility. Wastewater pump stations and certain key regulators were remotely controlled to allow in-system storage. Remotely controlled sluice gates were installed in one of the City's combined sewers to study the feasibility of using dry weather flow to flush sewers.

The report includes a detailed discussion and evaluation of the monitoring and remote control equipment, installation details, the concept of in-system storage, and the operation of the system based on an 18-month study period.

Detroit has found that many of the larger sewers are not used to capacity during storms. Utilization of system monitoring and remote control techniques has resulted in a significant reduction in the volume of combined sewer overflows and storm wastewater pumping as well as reduced operation and maintenance costs. Results of a combined sewer sampling program are being used to establish priorities for future system modifications.

This report was submitted in fulfillment of Project Number 11020 FAX, formerly 4-MICH-1, under the partial sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

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SECTION I

CONCLUSIONS

1. Detroit has significantly reduced the pumpage of storm wastewater to the Detroit and Rouge Rivers. This is a direct result of the sewer monitoring system.

2. Telemetered rainfall data gives the Systems Control Center one to three hours of advanced warning which is used to lower the hydraulic gradient of the system in anticipation of storm events. This system pumpdown has allowed for a more thorough capture of the "first flush" from storm wastewater.

3. Approximately six billion gallons of storm wastewater has been prevented from overflowing into receiving streams over the 18-month study period by application of in-system storage concepts. This figure does not include additional storage obtained by system pumpdown prior to storm events.

4. It is possible to capture all storm wastewater from intense, small spot storms. Occasionally, these storms have passed through areas without telemetering rain gages and operators did not have sufficient time to prepare the system for maximum storm wastewater capture.

5. A thorough analysis of combined sewer overflow reduction due to monitoring and remote control was not completely successful due to the limited duration of the study period. An extended dry period during a three-month test designed to gather base data provided little information. In addition, the incidence of similar rain events was not sufficient to provide enough data for correlation between rainfall amounts and combined sewer overflows to be made.

6. System monitoring has enabled the Detroit Metro Water Department (DMWD) to suspend pumping at the 750 mgd wastewater treatment plant for periods of up to six hours to perform maintenance and modifications without causing combined sewer overflows. In addition, monitoring has enabled DMWD to hold back flow from portions of the system to allow for sewer inspection and maintenance.

7. In-system storage, where possible, is considerably more economical than retention basins. Based on project costs under this grant and on the costs of retention basins constructed in the area, in-system storage costs utilizing existing sewers are less than $.02/gal. while the least expensive retention basin storage costs are approximately $.20/gal.

8. As the use of retention basins and in-system storage increases, both within the Detroit system and in the service area, system monitoring and

remote control will play an increasingly important role in the determination of regional dewatering procedures.

9. The use of dry weather flow to flush combined sewers following storage has been found to be an effective and relatively inexpensive method of preventing sewer deposits. Multiple barrel sewers are desirable storage facilities since flow may be routed among barrels to obtain scour velocity.

10. Many of the Detroit sewers widen into multi-gated dispersion structures at the outfall. Since only one of the gates is monitored, it has been found that overflows may occur and may not be recorded because the unmonitored gates were open, while the monitored gate was not.

11. Even with weekly regulator maintenance, outfall monitoring has detected overflows occurring during dry weather due to regulator blockage. Without monitoring, it was possible for raw sewage discharges to go undetected for up to a week. They are not detected immediately. Conversely, gates that are jammed or frozen shut can be identified and freed before flooding occurs due to backups within the system.

12. Remote control of pump stations for both dry weather flow and storm wastewater flow is practical, reliable and economical. Detroit has had over ten years' experience with remote control of the water distribution system and two years with the sewer system. No major failures have occurred in either system.

13. Both hydraulic and electric regulator operators have been found to be very reliable. In most cases, they require less maintenance than existing float-operated regulators, since they are less subject to fouling. Electric operators are slower acting than hydraulic systems but provide for simpler control and gate position indication. Hydraulic cylinders tend to drift but are usually less expensive and are intrinsically safe.

14. Time-pulse telemetering devices provide sufficient accuracy for analysis purposes and do not appear to be severly affected by transmission line noise. Continuous signals which are broken to indicate tipping bucket pulses and overflow status are subject to line noise and are not highly reliable.

15. Systems Control Center operator training is critical. Operators must have confidence in the remote control equipment and data displays. It is also essential that operators have a full and complete knowledge of their actions. They must, for example, be able to associate the pushing of a button with the activation of a 3,000 horsepower motor.

16. Careful consideration must be given to the control center layout and information displays. The trend recorders and a noisy alarm printer

are the most useful display devices for operations and should be in view of the operators. On the other hand, although the data loggers are also valuable, they can be distracting due to the noise generated when printing and should be located accordingly.

17. The simultaneous operation of the water distribution system and wastewater collection system by the same operators has proven to be economical since the wastewater collection system is practically attention-free during dry weather flow. However, during the time when rainfall occurs, the operators are approaching their functional limit.

18. Based on the results of combined sewer sampling, it is now possible to adjust float controlled regulators to permit selective overflowing. The regulators on the sewers containing greater pollutional concentrations may be set to remain open for longer periods than those on the other sewers during storm events.

19. Most commercially available sampling devices are not suitable for combined sewers. In order to obtain a representative sample, a large flow rate must be maintained with periodic drawoff for samples and the remaining wastewater returned to the sewer.

SECTION II

RECOMMENDATIONS

1. It is recommended that the monitoring system be expanded, since it has proven its value as an efficient means of system control and data acquisition. The expansion should include level sensors in all suburban retention facilities and major sewers, as well as at additional points within the Detroit system. Additional rain gages should be installed throughout the area to provide a denser and more complete network.

2. Additional major regulators should be remotely controlled to facilitate storm wastewater interception. Remotely controlled sluice gates, inflatable dams or other control devices should be installed at various locations to increase in-system storage volumes.

3. Overflow sensors should be installed on each backwater gate or dam wherever a sewer outfall consists of multiple dams or gates. In order to reduce telemetering costs and to conserve computer memory requirements, these sensors should be installed in such a manner that an overflow is recorded if one or more sensors detect an overflow condition.

4. Flow measuring and sampling devices should be installed at outfalls to obtain accurate measurement of volumes and pollution concentration variations of overflows. Priorities for overflow volume measurement and sampling should be based on the percentage of overflows as well as the sewer size.

5. It is recommended that combined sewer separation projects not be undertaken in the City of Detroit. Not only is the cost of such an undertaking prohibitive, but also, the amount of reduction in pollutants entering receiving streams from such systems is highly questionable.

6. It is recommended that combined sewer overflow treatment in the sewer system within the City of Detroit be held in abeyance in those areas where in system storage is applicable. Land availability, solids disposal problems, maintenance requirements, and existing technology severely limit the universal application of combined overflow treatment for a system as large and complex as Detroit's.

7. The in-system storage concept should be in the design and planning of all future relief sewers. In addition to high level relief ports, low level remote controlled gates should be installed to provide for flushing of the sewer after storage using dry weather flow.

8. Access openings of sufficient size to permit mechanized or manual cleaning should be constructed on sewers used for storage. The large debris which accumulates cannot be removed by any other means.

9. For similar future projects, in order to evaluate the effectiveness of system monitoring and remote control, base data should be collected before the starting of a new mode of system operation. A sufficient amount of data must be collected and analyzed so that a comparison between overflow frequency and duration versus rainfall can be made for each mode of operation.

10. Remotely controlled pump stations should be checked daily by traveling crews even though equipped with automatic, on-site monitoring equipment. Regulators and backwater gates should be inspected weekly. All installations should have on-site manual controls in case of communications failure and all control facilities within sewers should be designed to operate automatically and/or manually in the event of power failure.

11. At locations where partially submerged outfalls are protected by backwater gates, care must be taken to insure that gates are above maximum winter ice levels, if at all possible, so that blockage does not occur.

12. For those considering system monitoring and remote control, it is recommended that the computer system be large enough to function as a closed loop system. Initially, the system should act as a data acquisition system with operators controlling the system. As data is acquired and analyzed, the computer should make recommendations to the operators and note any disagreements. Ultimately, the computer may do the actual control with operators monitoring the operation.

13. Any data acquisition system should have either a backup computer or foreground-background capability so that programming changes may be made and tested without affecting the on-line system. This may result in additional first cost but would be worth the investment.

14. It is recommended that data acquisition systems have time-share data links to the suburban communities which contribute wastewater flow to the system. Instead of calling the Systems Control Center operators for information, they could interrogate the data acquisition system directly.

15. Frequency shift telemetering devices should be used to monitor combined sewer overflows. Pulse counts from tipping bucket rain gages should be stored on site and converted to time-pulse signals before telemetering.

16. Further research on combined sewer monitoring devices is needed. This should include automatic sampling equipment and flow measuring devices. Emphasis must be placed on reliability, cost and the combined sewer environment.

17. Where available, arrangements should be made with the U.S. Weather Bureau to obtain radar remoting system weather information by telephone lines, in order to give system operators maximum warning of approaching storms.

SECTION III

INTRODUCTION

The pollution resulting from combined sewer systems is a common problem which has plagued sanitary engineers in the older cities of this country (1). Overflows from these combined sewers have been increasing and they may now be classified as one of the primary pollution problems of this era (2-5). Our forebearers built these combined systems, which economically carry dry weather flow to interceptors, with the thought that overflows would be infrequent, of relatively short duration and sufficiently dilute so as not to harm receiving waters. However, with the growth and development of our urban centers which appear to have ever expanding impervious surfaces, these same sewers now spill a high portion of this mixed flow, untreated, to receiving streams during storm events. This report deals with applying the systems management concept to the Detroit combined sewer system to reduce overflow pollution.

The Detroit Metro Water Department (DMWD) acts as a regional agency and serves 95 communities in Southeastern Michigan with drinking water and provides wastewater interception and treatment service to 71 communities. A wastewater service area of 1075 square miles was under contract as of July, 1973 (6). Basically, the potable water needs of 45 percent of the population of the State of Michigan is served by DMWD. This same agency provides wastewater disposal service to over 35 percent of the State's populace.

The DMWD also has the responsibility for constructing, operating and maintaining the wastewater collection and water distribution systems within the city limits of Detroit. The sewer system was transferred to the DMWD from the Department of Public Works in mid-1966. The Wastewater Treatment Plant has been owned and operated by DMWD since its construction in 1939. The suburban communities which are served by DMWD have each retained responsibility for the operation and maintenance of their local systems. The suburban sewer systems range from totally combined to totally separated. These communities, many of which are joined into collection districts, connect to the Detroit system at various points on the city's perimeter and their flow is transported in both the interceptors and selected major combined sewers. The map on Figure 1 shows the status of wastewater disposal service in Southeastern Michigan as of July 1971. Sixteen communities have been added to the system since then.

The entire DMWD service area is connected to a primary treatment plant which is located near the confluence of the Detroit and Rouge Rivers which treats an average of 800 mgd. The capacity and the level of treatment are currently being upgraded under an agreement between DMWD and the Michigan Water Resources Commission. This agreement is one of the actions resulting from the 1965 Conference on Pollution of the Detroit River, Lake Erie and their tributaries (7). Initial

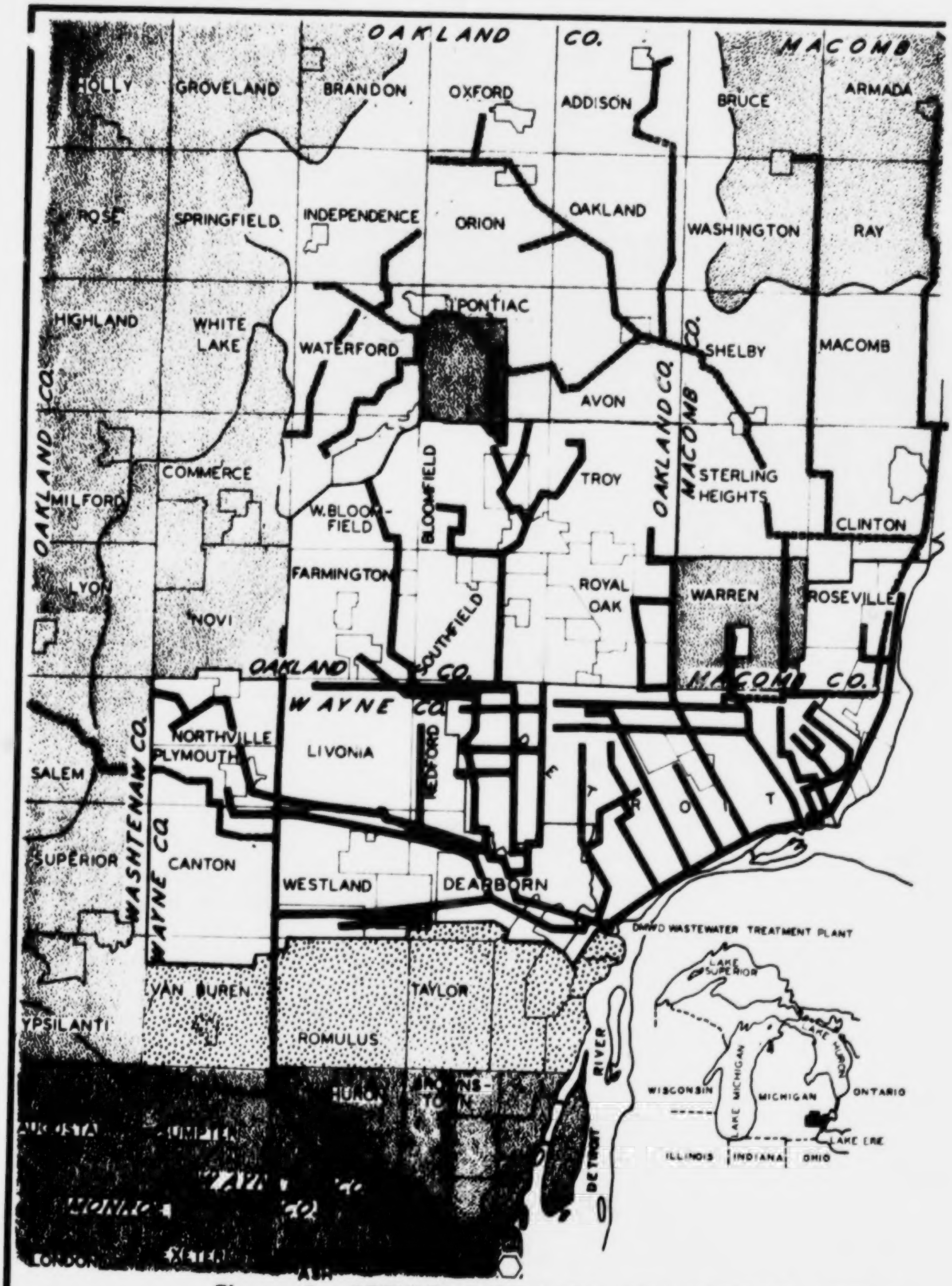
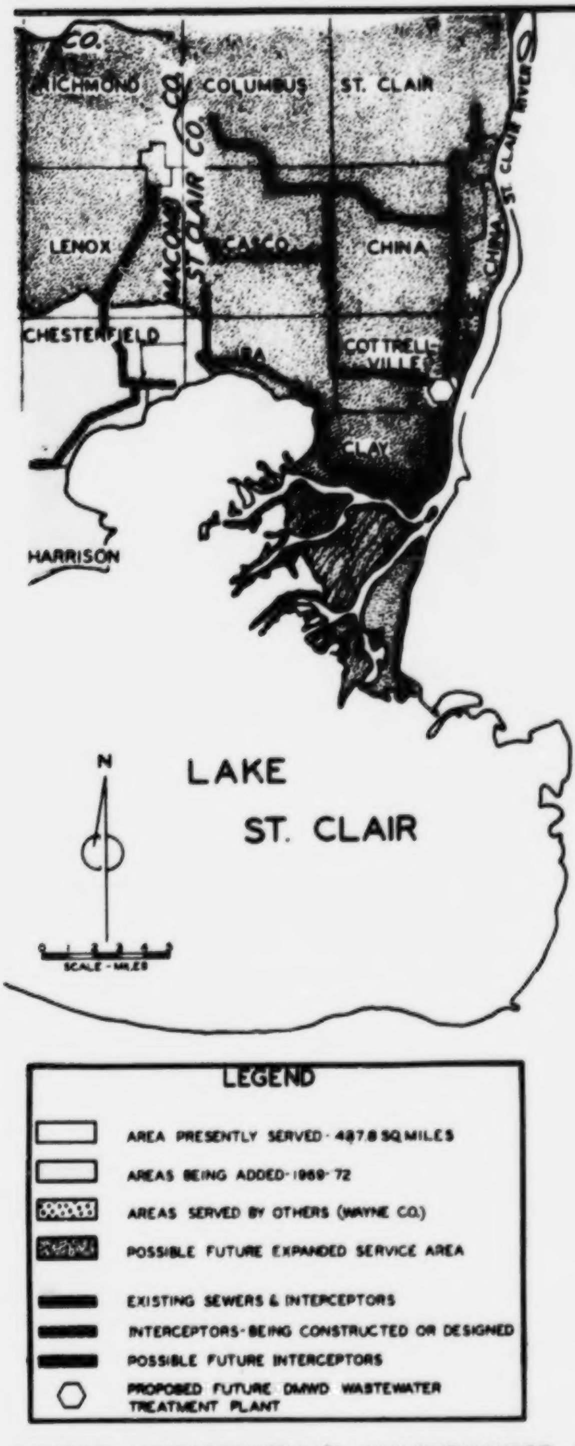


Figure 1 - SERVICE AREA OF THE DETROIT METRO


CO.
RICHMOND
COLUMBUS
ST. CLAIR
MACOMB CO.
ST. CLAIR CO.
ST. CLAIR RIVER
LENOX
CASCO
CHINA
CHINA
CHESTERFIELD
IRA
COTTRELL-VILLE
CLAY
HARRISON
LAKE ST. CLAIR
N
0 1 2 3 4 5
SCALE - MILES
LEGEND
AREA PRESENTLY SERVED - 487.8 SQ MILES
AREAS BEING ADDED - 1969 - 72
AREAS SERVED BY OTHERS (WAYNE CO.)
POSSIBLE FUTURE EXPANDED SERVICE AREA
EXISTING SEWERS & INTERCEPTORS
INTERCEPTORS - BEING CONSTRUCTED OR DESIGNED
POSSIBLE FUTURE INTERCEPTORS
PROPOSED FUTURE DMWD WASTEWATER TREATMENT PLANT

ESTIMATED POPULATION AND AREA SERVED
BY THE DMWD REGIONAL WASTEWATER DISPOSAL SYSTEM

Community	Est. Population Served by DMWD	Est. Area Served By DMWD in Sq. Mi.
Allen Park (part)	8,600	1.50
Berkley	22,600	2.60
Beverly Hills	13,600	4.10
Bingham Farms Village	100	0.10
Birmingham	26,200	4.80
Bloomfield Hills	3,700	5.20
Bloomfield Township	36,000	9.00
Canton Township	8,600	6.50
Center Line	10,400	1.70
Clawson	17,600	2.20
Dearborn	104,500	24.30
Dearborn Heights (part)	43,200	6.50
Detroit	1,511,500	138.6
East Detroit	45,900	5.10
Farmington	13,300	1.90
Farmington Township	36,000	24.00
Ferndale	30,900	3.90
Franklin Village	2,000	2.60
Garden City	41,900	5.70
Grosse Pointe City	6,600	1.10
Grosse Pointe Farms	11,700	2.70
Grosse Pointe Park	15,600	2.10
Grosse Pointe Shores	2,900	0.90
Grosse Pointe Woods	21,900	3.30
Hamtramck	27,200	2.10
Harper Woods	20,200	2.60
Hazel Park	23,800	2.80
Highland Park	38,400	3.00
Huntington Woods	8,500	1.50
Inkster	38,600	6.20
Keego Harbor	3,100	0.60
Lathrup Village (City of)	4,700	1.60
Livonia	110,100	36.10
Madison Heights	38,600	6.90
Melvindale	13,900	2.70
Northville	5,400	1.80
Northville Township	8,300	12.00
Novi	5,000	4.00
Novi Township	100	0.10
Oak Park	36,800	5.00
Pleasant Ridge	4,000	0.60
Plymouth	11,800	2.30
Plymouth Township	18,000	5.00
Pontiac Township (part)	2,200	1.8
Quakertown	100	0.10
Redford Township	71,900	11.10
Romulus Township (part)	2,000	1.80
Roseville	60,500	9.80
Royal Oak	86,800	12.10
Royal Oak Township	6,300	0.70
St. Clair Shores	88,100	11.90
Southfield	56,100	18.00
Sylvan Lake (part)	100	0.10
Troy	39,400	16.00
VanBuren Township (part)	3,200	8.00
Warren (part)	1,100	0.10
Wayne	21,100	6.30
West Bloomfield Township	14,500	16.20
Westland	60,000	20.20
Wood Creek Farms Village	100	0.10
TOTALS⁺	2,982,000	487.80

⁺AS OF 1971

WATER DEPARTMENT'S WASTEWATER TREATMENT PLANT

construction at the plant site began in 1966 and, currently, over $100 million dollars in construction is under contract. Advanced treatment facilities including a 300 mgd activated sludge process using oxygen aeration; a 150 mgd conventional activated sludge process; polymer injection facilities to aid primary settling; facilities to inject ferrous chloride for phosphate removal; and improvements to the chlorination system are now in service.

The May 19, 1966 Stipulation with the Michigan Water Resources Commission further required the City of Detroit to take immediate steps to decrease the frequency, magnitude and pollutional content of all combined sewer overflows from the City's sewer system to the Detroit and Rouge Rivers. The agreement also stipulated that a study be made of methods and costs of achieving these desired reductions. This project is a direct part of that study.

TOPOGRAPHY

The City of Detroit, containing 139.53 square miles within its corporate limits, is bounded on the southeast by the Detroit River and extends northerly for approximately 10 miles. Its westerly boundary generally follows the Rouge River. Nearly flat land slopes up gently from mean elevation of 576 (USGS) at the Detroit River northwesterly to a high elevation of 667. This flat slope gives way to increasingly rolling terrain and rises to elevations of 1,000 to 1,250 feet about 40 miles northwest of the river. The only exception to this northwesterly slope is in the extreme westerly section of the city where the ground slopes toward the west into the Rouge River Valley.

CLIMATOLOGY

Until 1966, Official Weather Bureau data was recorded at the Detroit City Airport which is located within a few miles of the urban center. Data is now gathered at the Detroit Metropolitan Airport which is near the southwest edge of the urban area.

The metropolitan area's climate is controlled by its location with respect to major storm tracks and the influence of the Great Lakes. The normal wintertime storm track is south of the City, and most passing storms bring periods of snow or rain. In summer most storms pass to the north, often with brief showers in the area and occasionally with heavy thundershowers or damaging winds. The Great Lakes smooth out most climatic extremes. Precipitation is distributed evenly through all months of the year. The most pronounced lake effect occurs in the colder part of the winter. Arctic air moving across the lakes is warmed and moistened. Cold waves approaching from the northern plains are much reduced in intensity. This causes an excess of cloudiness in the winter.

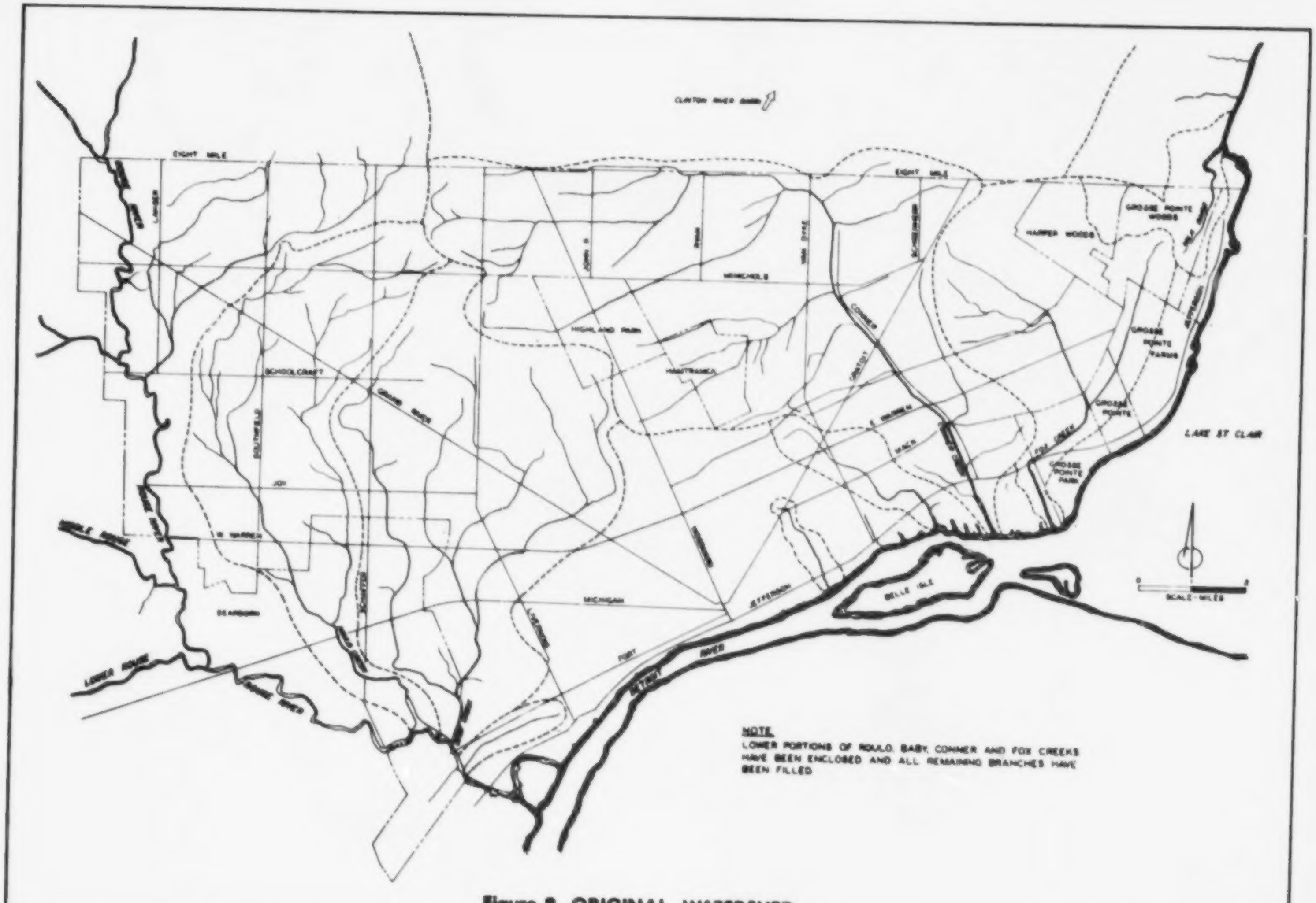
Summers in the area are warm and sunny. Brief showers usually occur every few days, but often fall on only part of the metropolitan area. Extended periods of drought are unusual. Each year sees two or three series of days with temperatures in the nineties. The high temperatures are often accompanied by high humidity. Most summer days are quite comfortable, and air conditioning is required only intermittently. In winter skies are cloudy and temperatures average near the freezing point. Day-to-day changes are not large. The temperature drops to near or a little below 0°F once or twice each year. Winter storms may bring rain, snow, or both. Freezing rain and sleet are not unusual. Most wintertime precipitation is more or less steady and continues for several hours. Snowstorms average about three inches, but heavier amounts accumulate several times each year (8).

Local climatic variations are due largely to the immediate effect of Lake St. Clair and the urban "heat island". On warm days in late spring or early summer, lake breezes often lower afternoon temperatures by 10°F to 15°F in the eastern part of the City and the northeastern suburbs. Less pronounced local lake effects occur at other times of the year. The urban effect shows up mostly at night. Comparative readings show nearly uniform maximum temperatures over the metropolitan area. Minimum readings at Metropolitan Airport, in a semi-rural area, average 2.3°F lower than those at City Airport, in a typical residential area, and 4.1°F lower than those in downtown Detroit. On humid summer nights or on very cold winter nights, the difference can exceed 10°F.

The slope of the land dries northwest winds and has an opposite effect on southeast winds. Northwest winds in winter bring snow flurries to all of Michigan. Flurries build up snow accumulations in many places but in Detroit, they rarely cause enough snow to be measured. Summer showers moving from the northwest also weaken and sometimes dissipate as they approach Detroit. On the other hand, much of the heaviest precipation in winter comes with southeast winds, and this may be heavier in the Detroit area, especially to the northwest of the City, than in other places affected by the same storms (9).

WASTEWATER COLLECTION SYSTEM

As the wastewater collection system evolved, it generally followed the slopes of the natural drainage basins shown in Figure 2. The original settlement was in the district that drained directly to the Detroit River. The city gradually spread outward until it reached its present size in 1926. The resultant system within the city contains 2,950 miles of sewers.



NOTE
LOWER PORTIONS OF ROULO, BABY, CONNER AND FOX CREEKS HAVE BEEN ENCLOSED AND ALL REMAINING BRANCHES HAVE BEEN FILLED

Figure 2 - ORIGINAL WATERSHED

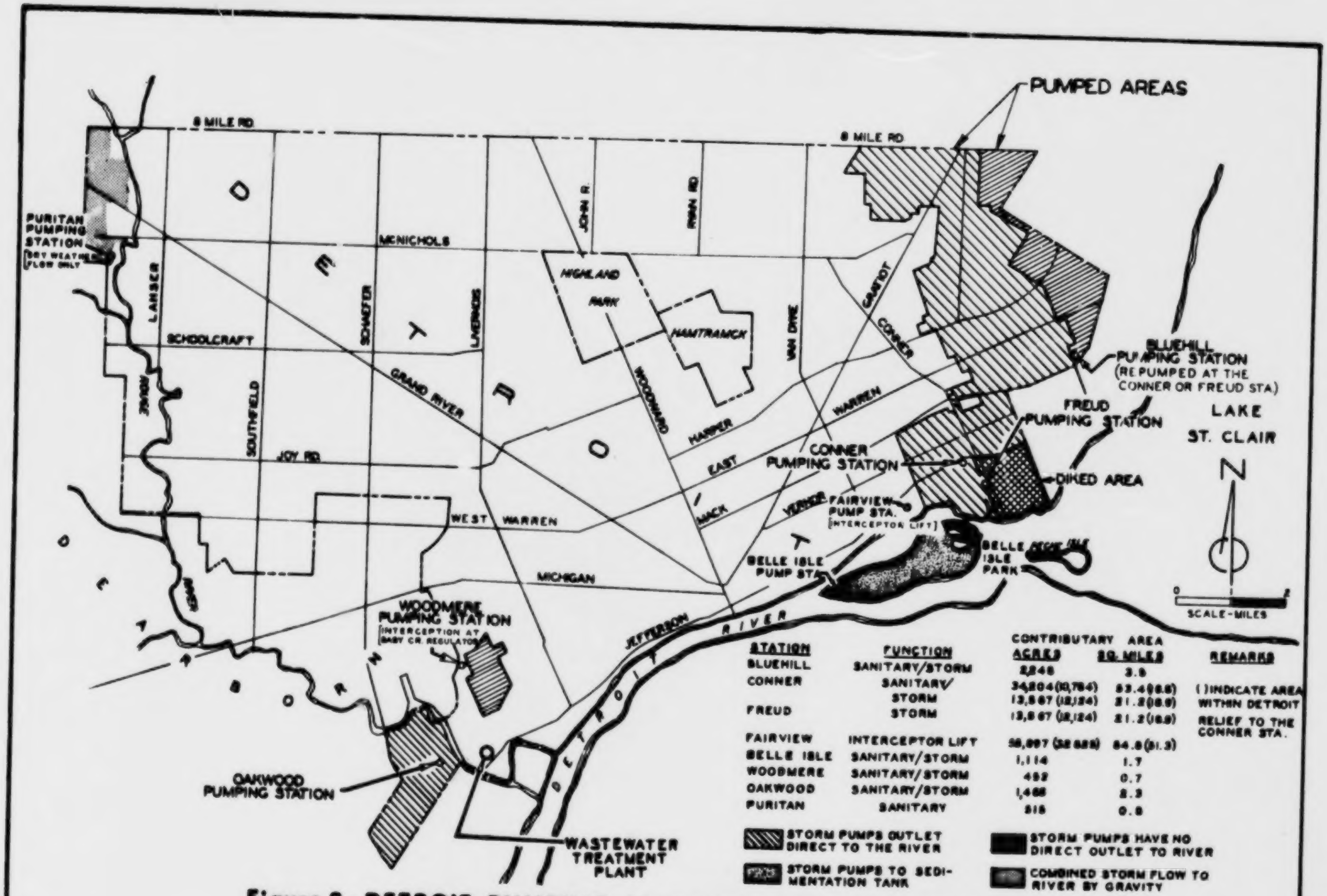
Approximately 85 percent of the nearly 140 square miles within Detroit are drained by gravity sewers with the remaining 15 percent requiring pumpage. Figure 3 shows the areas within Detroit served by combination sanitary/stormwater pumping stations. Flow from the area served by the Bluehill Station requires repumping by the Conner or Freud Stations for both sanitary and storm discharge. The diked area shown in the far east corner of the city is also drained through the Conner Pumping Station. This area, which was reclaimed from the Detroit River by enterprising real estate mean over forty years ago during an extended period of low water, is several feet below mean river elevation.

Nearly 98 percent of the wastewater collection system is of the conventional combined type with single house connections to convey sanitary wastewater, runoff collected by the roof conductors and seepage from the footing drains. Figure 4 shows the combined and separated areas, as well as the Detroit Interceptor System. The sanitary wastewater from the separated area enters the interceptor by gravity, while the storm wastewater from this area is drained through the deeper Conner-Freud pumped system.

The Detroit River Interceptor varies in size from 8'-0" ID at the city limits to 16'-0" ID at the Wastewater Treatment Plant. All flow from the east side pumped areas plus the flow from the Conner Gravity System, is lifted at the Fairview Station and continues by gravity to the wet well at the treatment plant. Along the Rouge River the Oakwood and Northwest Interceptors collect flow from the various combined sewers flowing into the Rouge River Valley. The Oakwood Interceptor is 12'-9" ID. The Northwest Interceptor, which crosses under the Rouge River at several points through inverted siphons, varies in size from 4'-0" ID in the upper reaches to 10'-0" ID where it joins the Oakwood just north of the treatment plant.

The Detroit wastewater collection system has 76 possible points of overflow, not including the bypass on the discharge side of the pumps at the treatment plant and an emergency outlet at the lower Rouge River Siphon. Diversion and regulating devices which allow flow to be transferred from the combined sewers to the interceptors include 45 float-controlled regulators, 22 diversion weirs, 2 sluice gates, 2 orifice regulators, with the remaining 5 overflow points located at pumping station. Seventy-three points overflow by gravity and the remaining three require storm pumpage.

Figure 5 shows a typical float controlled regulator, the function of which is to transfer flow from the combined sewer to the interceptor. All of the gravity combined sewers served by the Detroit River Interceptor employ this type of regulator. This regulator also serves two of the four lines connected to the Oakwood Interceptor and one of the twenty-six lines connected to the Northwest Interceptor. Some 77 percent of the float controlled regulators were manufactured by the Brown and Brown Company, with the majority of the remainder manufactured by the McNulty Engineering Co.



STATION	FUNCTION	CONTRIBUTARY AREA ACRES	CONTRIBUTARY AREA SQ. MILES	REMARKS
BLUEHILL	SANITARY/STORM	2,246	3.5	
CONNER	SANITARY/	34,204 (10,784)	53.4 (16.8)	( ) INDICATE AREA WITHIN DETROIT
	STORM	13,567 (12,124)	21.2 (18.9)	
FREUD	STORM	13,567 (12,124)	21.2 (18.9)	RELIEF TO THE CONNER STA.
FAIRVIEW	INTERCEPTOR LIFT	58,097 (32,888)	84.8 (51.3)	
BELLE ISLE	SANITARY/STORM	1,114	1.7	
WOODMERE	SANITARY/STORM	452	0.7	
OAKWOOD	SANITARY/STORM	1,465	2.3	
PURITAN	SANITARY	515	0.8	

Figure 3 - DETROIT PUMPING STATIONS AND AREAS SERVICED

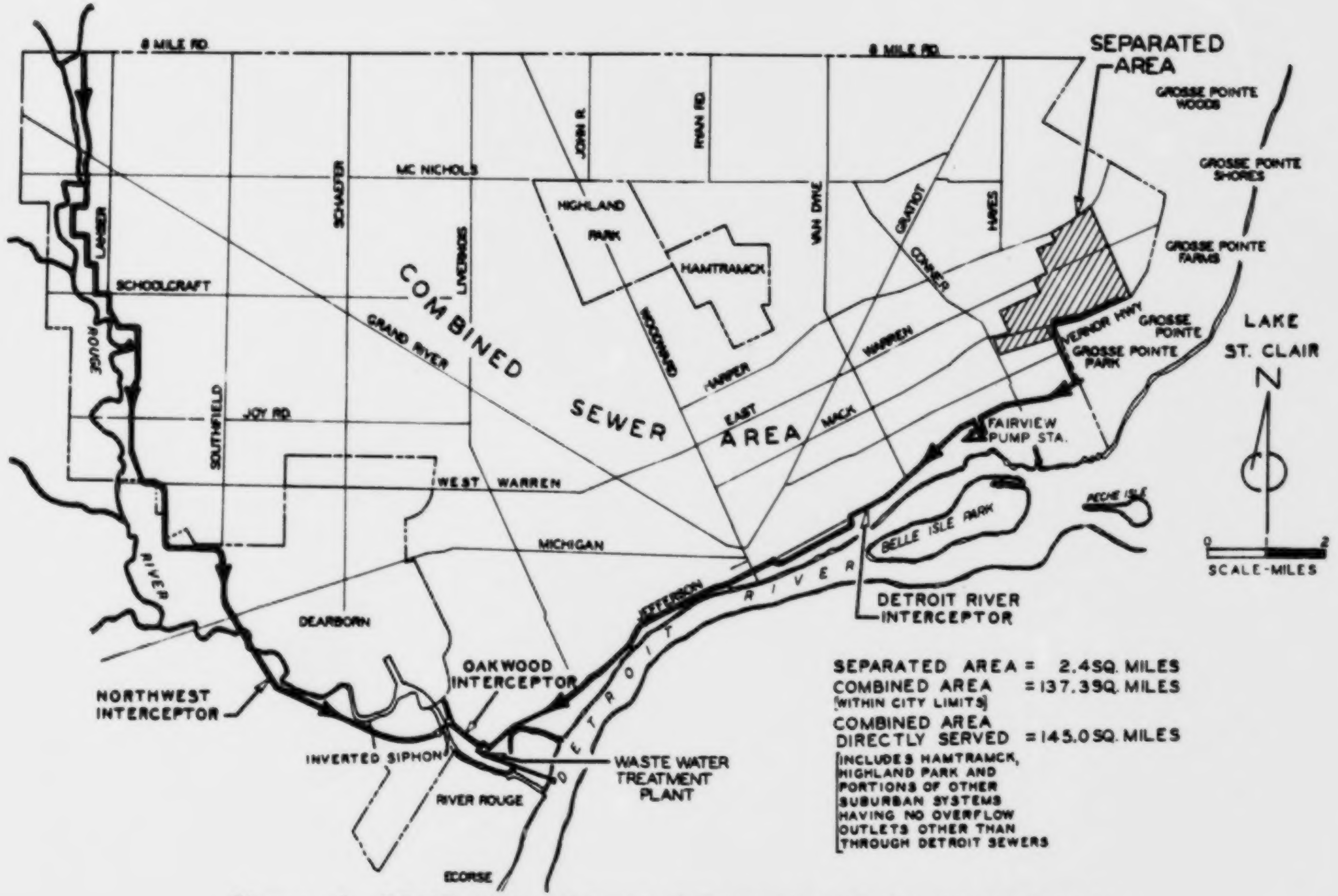


Figure 4- COMBINED VERSUS SEPARATE AREAS IN DETROIT

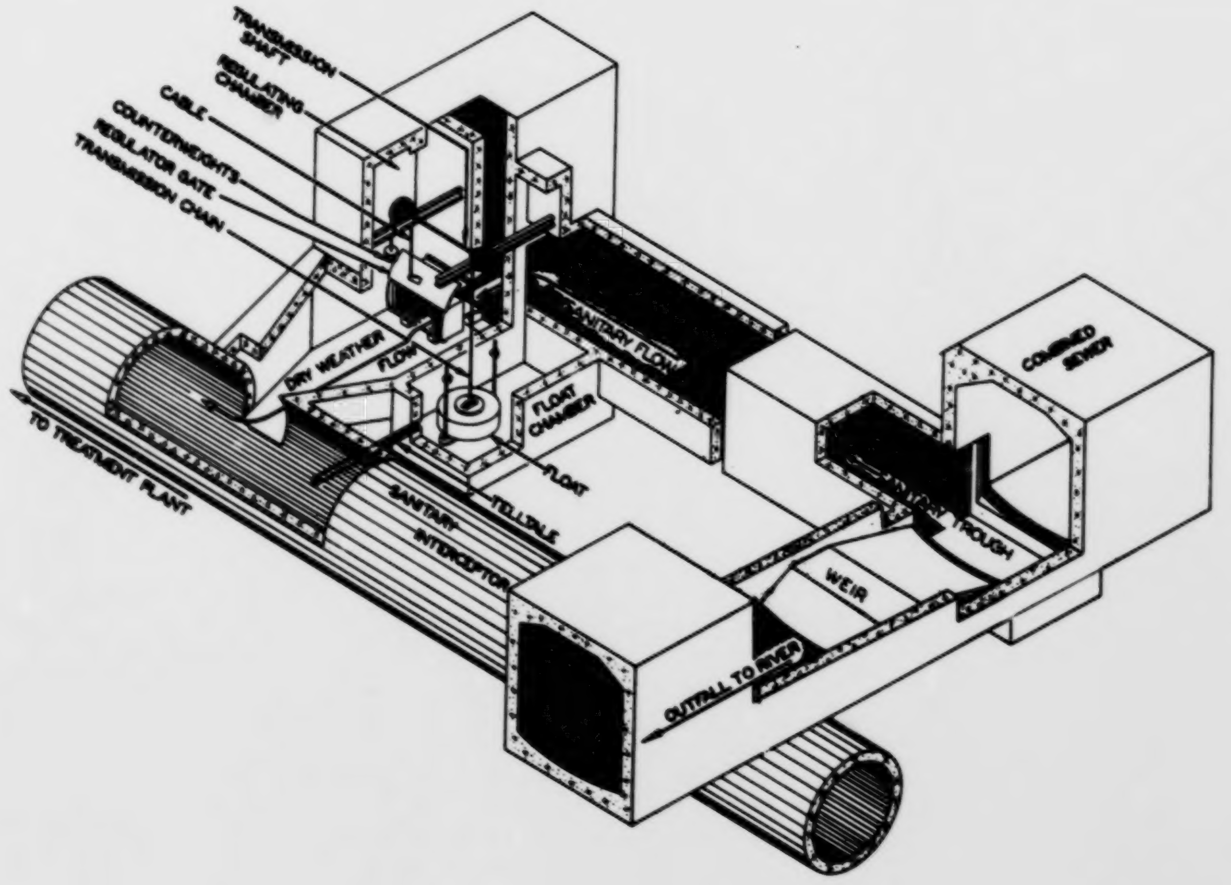


Figure 5 -FLOAT CONTROLED REGULATOR

All but three of these regulators are controlled by the level of flow within the interceptor by means of a 6-inch tell tale pipe connected between the float chamber and interceptor. The normal settings for these regulators cause flow restrictions to begin when the interceptor reaches a depth of seven tenths with all flow stopped at the eight tenths point. When the regulator closes and flow is diverted into the outfall line, a combined sewer overflow does not immediately occur because all outfalls served by these regulators are protected from river backflow with backwater gates or weirs. Thus, most of the sewers must head up before an overflow can commence.

There were five major outfalls located on the upper reaches of the Northwest Interceptor without sufficient backflow protection. Urbanization of the suburbs located in the upper Rouge River Basin cause the river to crest at a higher elevation during major storm events. Sometimes the flow tops existing weirs and floods out a portion of the Interceptor. This problem should be alleviated by early 1975 when the last of the backwater gate construction is completed.

FACTORS AFFECTING SELECTION OF MONITORING AND REMOTE CONTROL

To fulfill the agreement with the Michigan Water Resources Commission, various alternatives for controlling combined sewer overflows have been under consideration. Among the alternatives considered were: the concept of a systems management approach utilizing sewer monitoring and remote control of pumping stations and selected regulator gates to affect in-system storage; complete separation of sanitary and storm sewers to eliminate combined wastewater overflows; retention basins to capture storm wastewater; and combinations thereof.

The mode of operation for the wastewater collection system at the time of these studies was primarily single unit control (10). The regulators, as designed, functioned without regard to conditions throughout the remainder of the system. Only minimal coordination of pump station operations was practiced. The east side complex of pumping stations was operated with the thought of preventing basement flooding and storm pumpage occurred even during relatively minor storm events. When the Conner Storm Station went on line, the Fairview Station dropped out so as to reduce flow to the treatment plant regardless of conditions in the westerly portion of the City. Because an overall status of the system was not available, each station had to operate within predetermined limits. This practice has been common throughout the nation.

Taking into account the wastewater collection system as described and the current mode of operation, the following factors influenced the decision to apply the systems management approach:

1. The DMWD had been monitoring water distribution main pressure and reservoir levels and remotely controlling water booster stations since 1962 and was therefore familiar with monitoring and remote control.

2. There existed large areas served by pumping stations whose tributary lines could be used as storage areas during small storms.

3. The grades of the sewers, either rectangular boxes or cylinders, were relatively flat which would permit substantial storage near the outfalls.

4. The existing float controlled regulators appeared to be accpetable for conversion to remote controlled operation.

5. Most of the 76 outfall points are equipped with backwater gates and/or dams which serve as automatic retention devices.

6. Interconnections existed throughout the system which could be used for flow routing if remote controlled gates were added.

7. From knowledge of the particular industries connected to certain sewers, there would apparently be a wide variation in the quality of dry weather flow. If this marked quality difference carried over into the storm wastewater flow, it might be possible to favor interception of the worst pollutants.

8. Weather patterns showed that uniform rainfall did not always occur across the city; especially in the summer when brief scattered showers were common.

9. By monitoring the system, the information necessary to establish the existing conditions and thence to be able to determine the best methods to eliminate combined sewer overflow pollution would be possible.

SECTION IV

IN-SYSTEM STORAGE

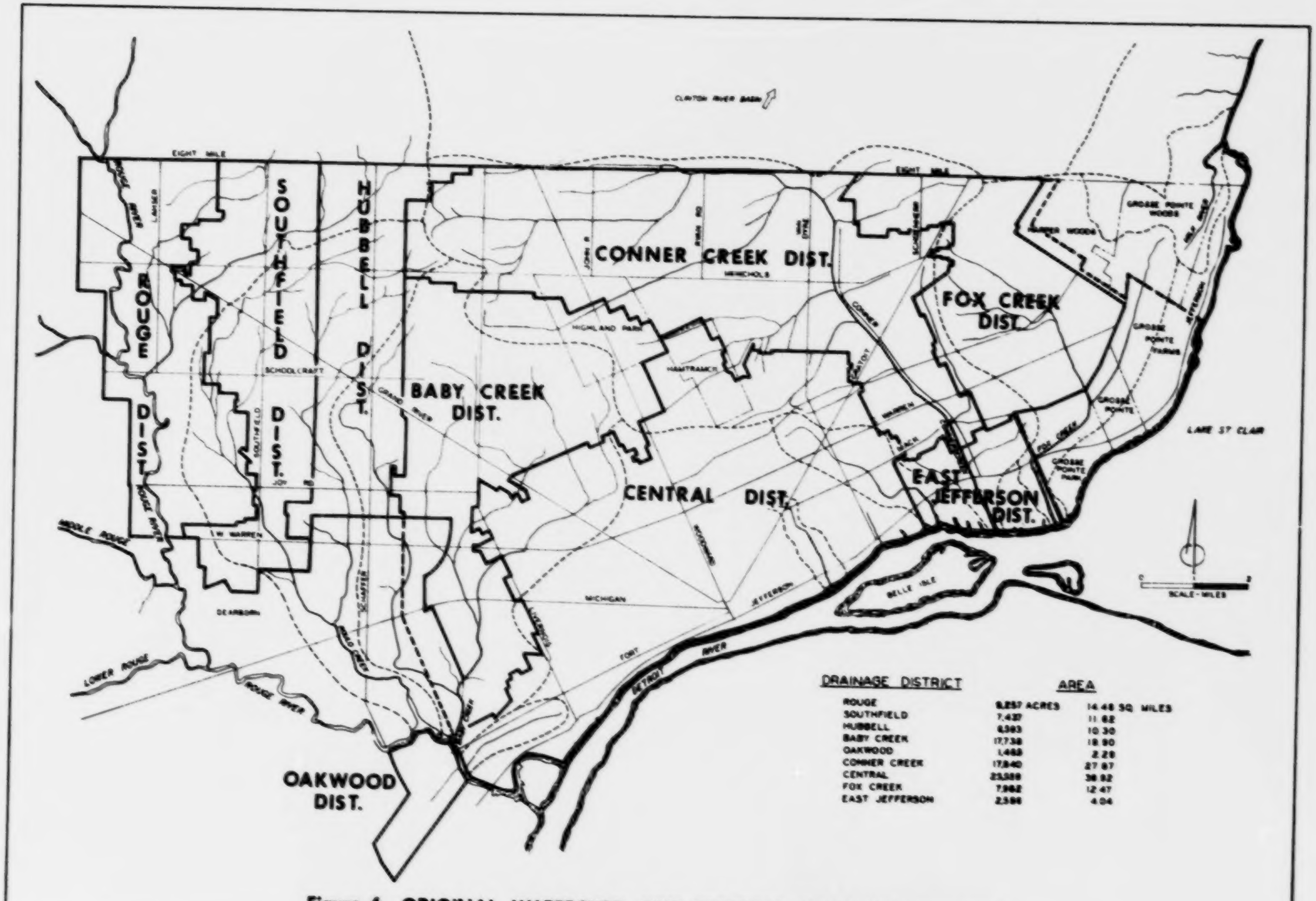
Large volumes of potential in-line storage exist within the Detroit combined sewer system since the relatively flat topography dictated that the lower reaches of the major combined sewers be built on flat slopes with increased cross-sectional areas to avoid the use of pump stations at the rivers. Figure 2 illustrates Detroit's original watershed showing the major natural drainage basins. This Figure may be compared with Figure 6 which shows the present drainage districts in relation to the original watershed. It should be noted that the Conner Creek, Baby Creek and Hubbell-Southfield districts each discharge through a single outlet requiring the lower reaches of these combined sewers to be of substantial size. All flow from the Fox Creek district, except for the sanitary flow from the previously discussed small separated area, requires pumping for both storm and sanitary wastewater discharge. Flow from the Rivard sub-district of the Fox Creek System which is served by the Bluehill Wastewater Pumping Station requires an additional lift at the Conner Station. The relatively small Oakwood District also requires pumpage of all flows. The Central District is composed of numerous narrow sub-districts perpendicular to the Detroit River. These relatively narrow sub-districts, each with its own combined sewer, evolved as the strip farms originally established by the early 18th century French settlers gave way to subdivisions as the city expanded outward. The Rouge District is also serviced by strip sub-districts draining westerly to the Rouge River.

Along both the Detroit and Rouge Rivers, there is a mixture of backwater gates and/or diversion weirs. The particular type of installation depended on the depth of the sewer and the maximum river level that could be expected at the outfall. The majority of the float-controlled regulators in the system are controlled by the interceptor level. Thus, in many cases, the regulator will close but no overflow will occur until the combined sewer heads up enough to top the diversion weirs or open the backwater gates. Therefore, although the volumes of storage may be minimumn in the narrow drainage areas within the Central district, storage becomes substantial when the large outlet sewers such as those of the Baby Creek and Conner Creek districts are considered.

The in-line storage of flow within any sewer is dependent upon the following factors: size of box or cylinder; slope of the conduit; time elapsed since previous rain; available height in sewer before gates open; the level of the Detroit and Rouge Rivers; and available capacity in the interceptor.

CONTROLLED STORAGE

The in-system storage potential at locations where remote control facilities were installed is shown in Table 1. The volumes shown for the



DRAINAGE DISTRICT	AREA	
ROUGE	9,257 ACRES	14.46 SQ. MILES
SOUTHFIELD	7,437	11.62
HUBBELL	6,593	10.30
BABY CREEK	17,738	18.90
OAKWOOD	1,468	2.29
CONNER CREEK	17,840	27.87
CENTRAL	23,559	36.82
FOX CREEK	7,982	12.47
EAST JEFFERSON	2,586	4.04

Figure 6 -ORIGINAL WATERSHED AND EXISTING DRAINAGE DISTRICTS

TABLE 1

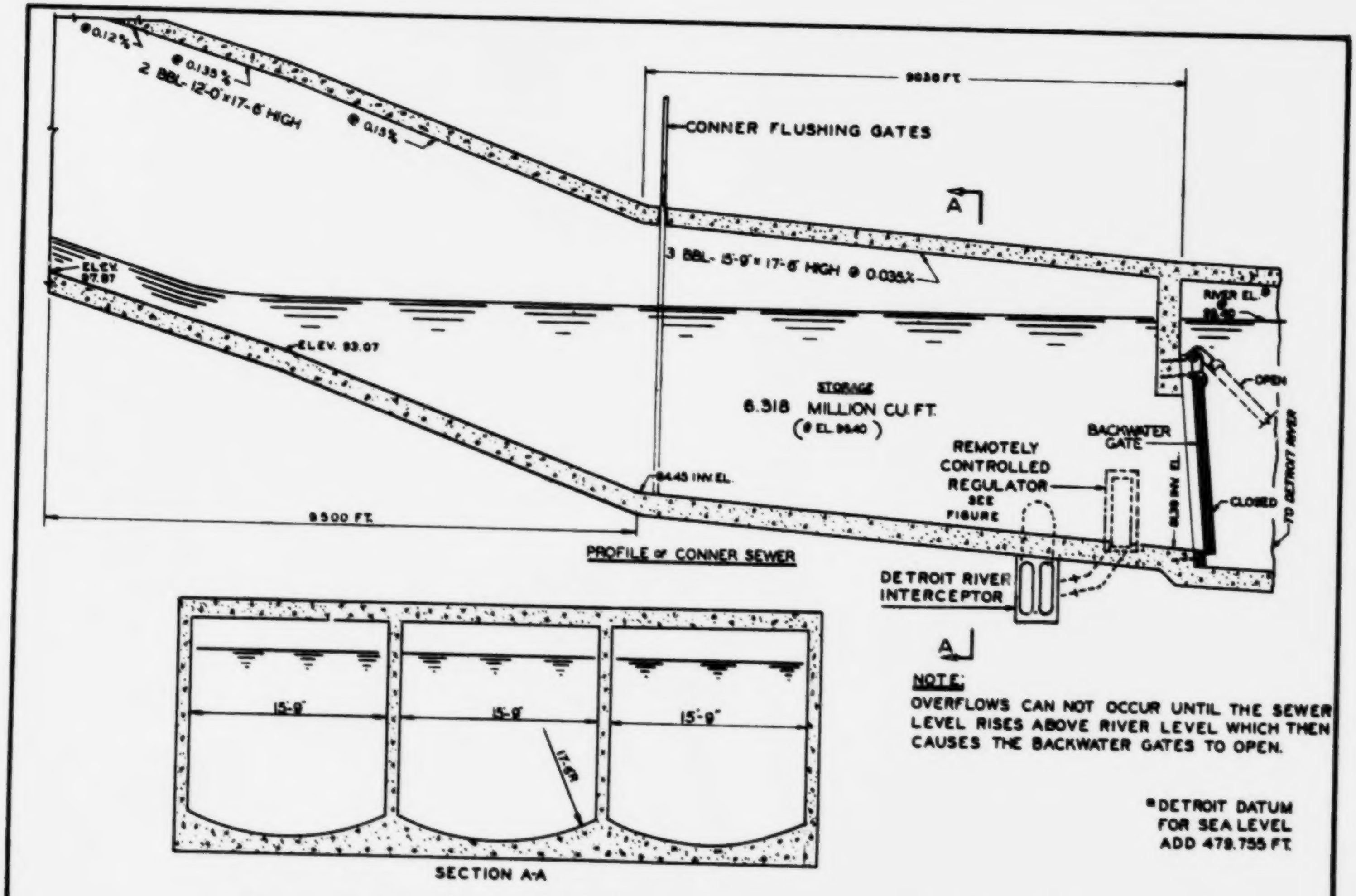
IN-SYSTEM STORAGE POTENTIAL

Storage Location	Size	Storage Volume (Million Gallons)
Conner Gravity Outfall	15'-9" wide x 17'-6" deep triple barrel box	47.0
Hubbell Southfield Outfall	14'-6" wide x 12'-0" deep double barrel box	3.5
Baby Creek Outfall	14'-6" wide x 17'-6" deep triple barrel box	52.0
Bluehill	Pump Station	6.8
Conner	Pump Station	3.8
Freud	Pump Station	20.0
Woodmere	Pump Station	2.0
Oakwood	Pump Station	4.0

outfalls were calculated by assuming static level conditions in the sewer and the normal river level acting against the backwater gates. Backwater volumes and upstream storage were not considered. Volumes shown for the pump stations were calculated based on the maximum level that could be reached in the wet well without causing upstream flooding. The volumes shown include the wet well and inlet sewer potential storage.

Figure 7 shows the Conner Gravity sewer. Note the relatively flat grade of the triple box section. For this sewer, normal Detroit River levels are such that a depth of storage of approximately 15 feet is available before an overflow will occur. The storage volume shown in Table 1 was based on the normal river elevation shown.

Although the Hubbell-Southfield Outfall is a 14'-6" x 12'-0" double box, it does not provide as large a storage capacity as might be expected. This outfall is equipped with backwater gates and storage depends on Rouge River levels. At this location, the river level averages about 1.5 feet above invert level. The figure shown for storage is based on the 1.5 feet depth of available storage in the outfall which would not cause the backwater gates to open.



NOTE:
OVERFLOWS CAN NOT OCCUR UNTIL THE SEWER LEVEL RISES ABOVE RIVER LEVEL WHICH THEN CAUSES THE BACKWATER GATES TO OPEN.

*DETROIT DATUM
FOR SEA LEVEL
ADD 479.755 FT.

Figure 7 -STORAGE POTENTIAL IN THE CONNER GRAVITY SYSTEM

As with most cities there has been a dramatic growth of suburbs within the past 15 years in the Detroit area. This suburban growth has resulted in an urbanization of most of the Rouge River watershed north of Detroit. Consequently, the time of concentration for the runoff into the Rouge River has diminished. In addition, the fluctuations in the river level are becoming increasingly greater. As the time of concentration for the Rouge River shortens, it is approaching the time of concentration of some of the major sewers on the west side of Detroit -- notably the Hubbell-Southfield. The net result is that the river level rises to such a point that substantial storage now takes place in the Hubbell-Southfield sewer. Records indicate that at times the Hubbell-Southfield backwater gates will not open until the depth of water in the sewer is 10 feet or more. With 1.5 feet of water holding the backwater gate there is only 3.5 million gallons of storage. With 8 feet of water holding the backwater gate there is 23 million gallons of storage. This increased storage is not a result of the Monitoring and Remote Control project and was consequently not included in any storage calculations. However, the amount of storage at the Hubbell-Southfield outfall was many times that which had been listed in the table.

UNCONTROLLED STORAGE

There are additional locations in the Detroit wastewater collection which contribute substantial volumes of storage. Unfortunately the storage which takes place in these locations is not controlled from the Systems Control Center. Based on river level data, suburban flow, treatment plant records and sewer profile drawings, a conservative estimate of possible uncontrolled storage is 150 million gallons per storm. Plan-profile drawings of three sewers, as shown in Figures 8, 9 and 10, illustrate the uncontrolled storage potential. Notice the relative flat grades of the sewers and the relatively large size.

A portable level recorder was located on the Clark Avenue Relief Sewer about 400 feet south of Toledo Avenue as shown on Figure 8. With the Detroit River level at elevation 95 (Detroit Datum), levels in this sewer could rise to approximately 10 feet at the sensor point before an overflow would occur. At this level there is approximately 11.5 million gallons of storage capacity available.

The zero point on the chart corresponds to a depth of 1 foot in the sewer. Thus, an overflow should occur when the chart reads 9 feet. This is illustrated in Figure 11. Note that when the wastewater level approached 10 feet (9 feet on the chart), the level fluctuated as the backwater gate opened and closed. Approximately 18 hours were required to dewater the sewer. Figure 12 shows the levels over a period in which rainfall occurred several times. Approximately 33 million gallons were stored in this period. This example serves to illustrate the potential volume of uncontrolled storage.

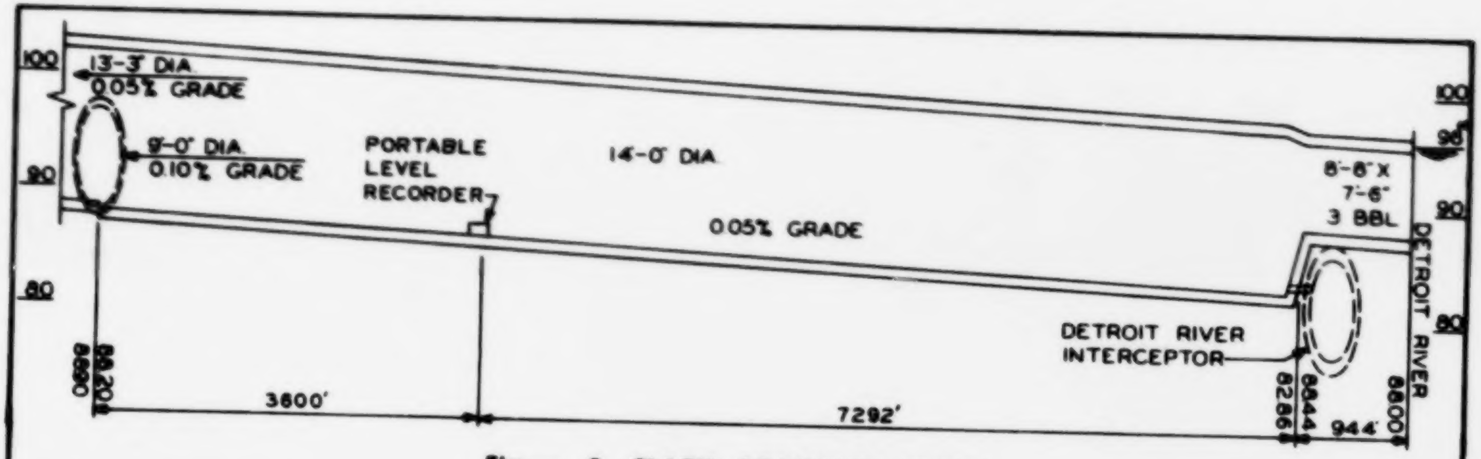


Figure 8 -CLARK COMBINED SEWER

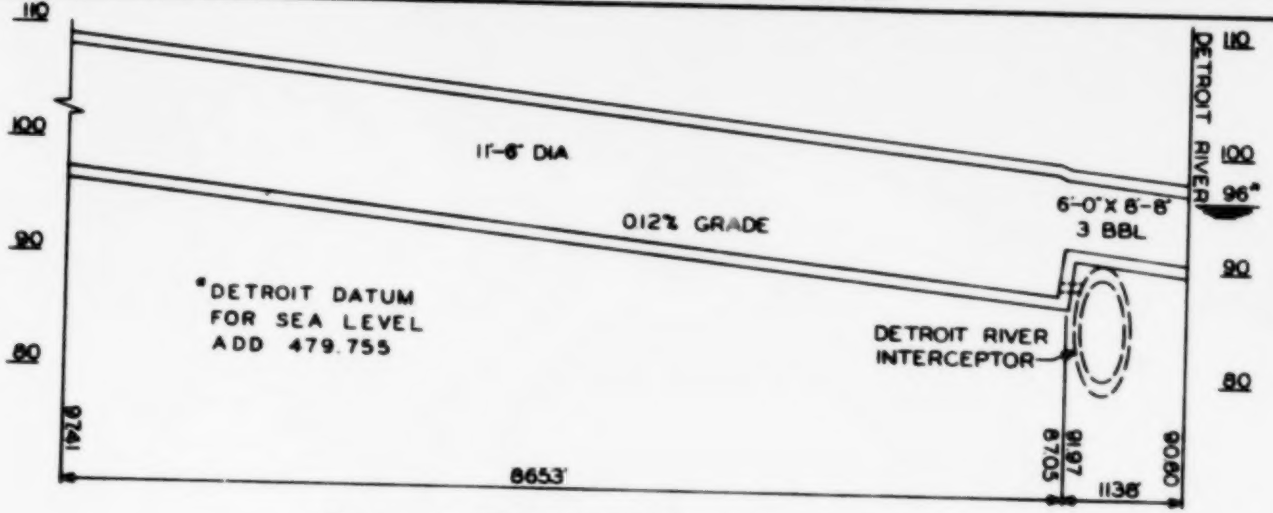


Figure 9 -JOS CAMPAU COMBINED SEWER

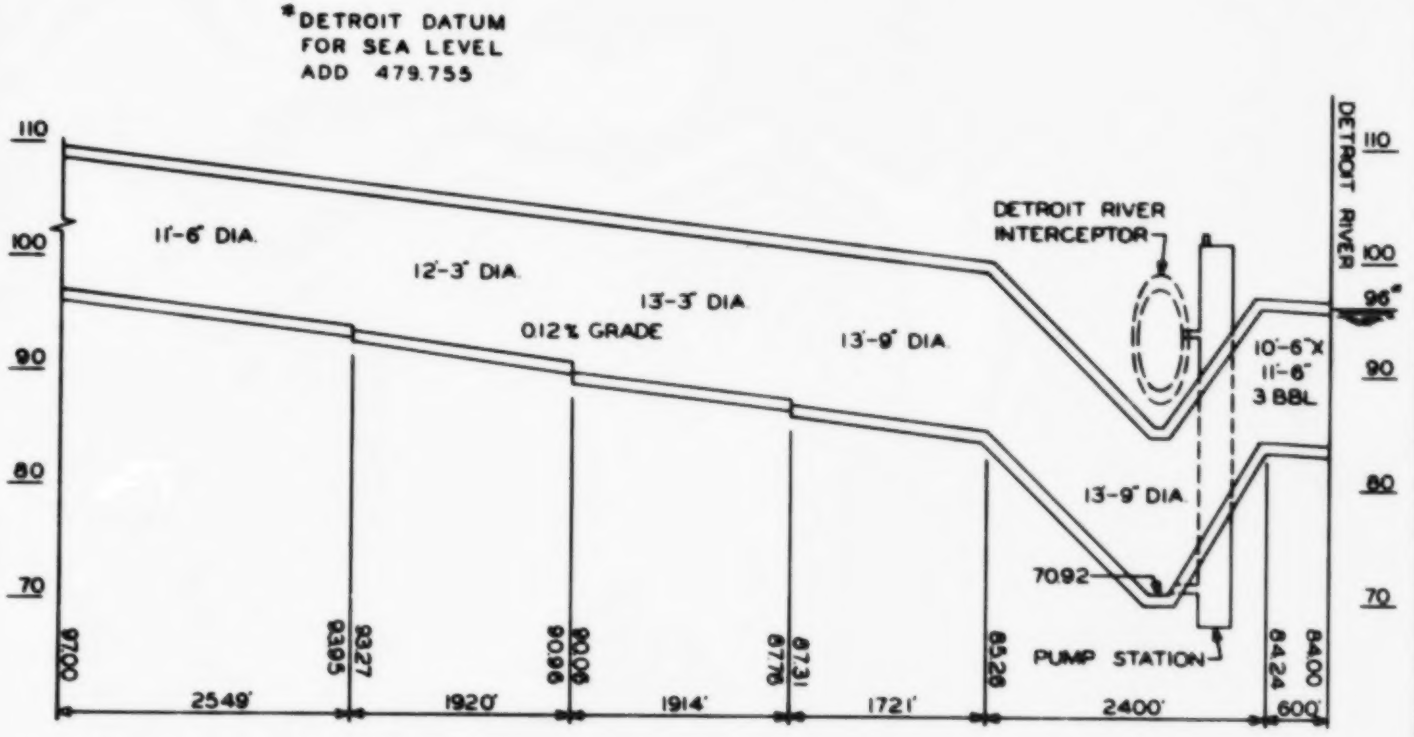


Figure 10 -FISCHER COMBINED SEWER

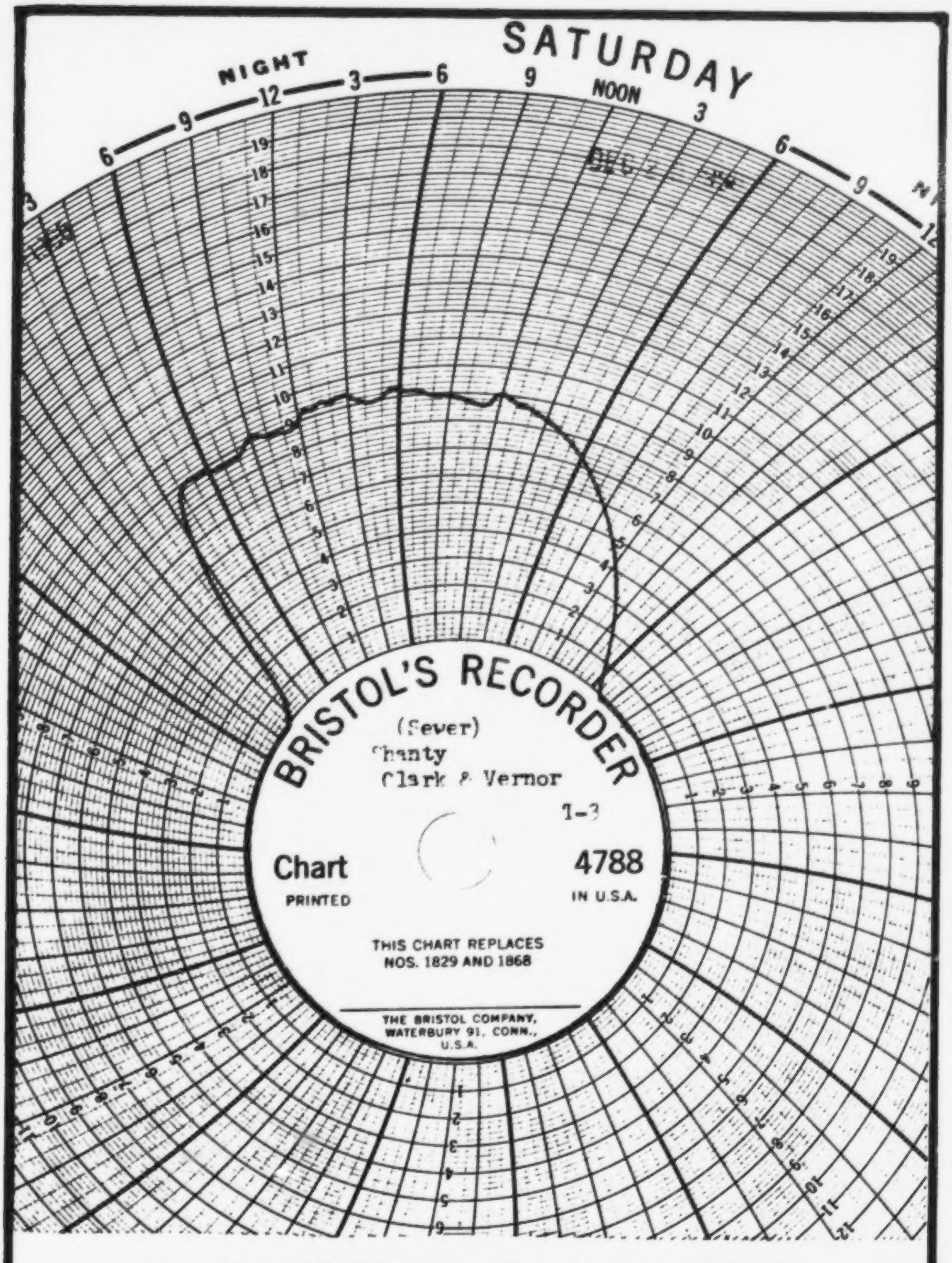


Figure 11-UNCONTROLLED STORAGE WITH OVERFLOW

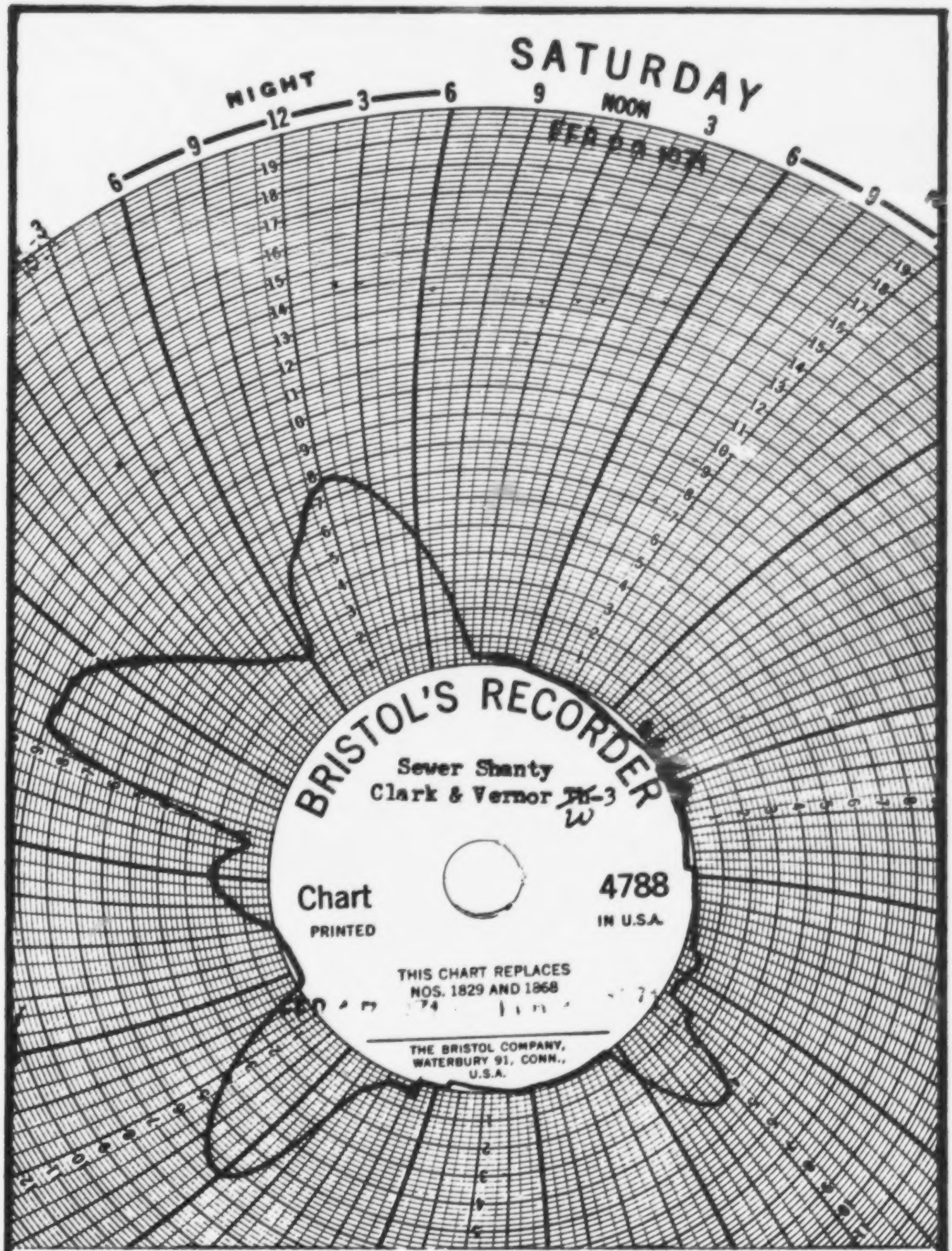


Figure 12 - UNCONTROLLED STORAGE WITHOUT OVERFLOW

SLUDGE DEPOSITS IN SEWERS USED FOR STORAGE

One of the major problems associated with in-system storage is sedimentation. Velocities below 2 feet per second usually cause graded sedimentation with coarse deposits occurring upstream and finer deposits downstream as the velocity approaches zero (11, 12).

In 1959 the Baby Creek barrels and the Conner barrels were used to store dry weather flow by manually adjusting the regulators in an attempt to moderate the variations in the hydraulic load on the treatment plant. Sedimentation occurred at both locations. In 1965, when the treatment plant began to operate the system at a lower hydraulic gradient, the deposits in the Baby Creek were gradually moved to the treatment plant. Some initial problems of overloading the grit chamber and breaking flights in the primary tanks resulted. The sediment deposits in the Conner barrels were not dislodged by the lower gradient, however. This was due both to the design of the sewer and its distance from the wastewater Treatment Plant. At the transition section from two 12'-0" x 16-6" barrels at 0.135% grade to three 15'-9" x 17'-6" at 0.035% grade, a natural velocity slow-down occurred and the lower gradients did not increase the velocity enough to prevent sedimentation.

Inspection of the three Conner Gravity Sewer barrels in 1967 revealed that the two outside barrels were partially filled with deposits. The center barrel remained relatively clean, cluttered with larger pieces of concrete and brickbats since the deposits in the outer barrels had formed natural dams which forced all dry weather flow through the center barrel with increased velocity. Near the transition section, the east barrel contained deposits approximately 7 feet deep. The west barrel, as shown in Figure 13, had collected about 7-1/2 feet of sludge. From this high point, deposits in both barrels extended downstream about 7,000 feet and ranged from 5 to 6 feet in depth for the first 4,000 feet as indicated in Figure 14. The deposits then gradually tapered down to the invert of the sewer. The volume of these deposits was over 30,000 cubic yards (6 million gallons).

Several sample holes were dug at the time of this inspection. The particular sample hole shown in Figure 15 was dug approximately 40 feet downstream of the transition where the deposits were about 6 feet deep. The deposits at this point contained small stones, gravel and coarse sand. As is evident in the figure, the deposits were quite compact. Another sample hole dug approximately 250 feet downstream of the transition was reported to have contained soft silt and sludge with little granular material. The material flowed easily into the hole that was dug by shovel.

Following the initial inspection, samples were taken and a sieve analysis was performed and a determination of the percent organic content was made. The results are summarized in Table 2. Sample No. 1 was taken at the transition section, Sample No. 2 through Sample No. 8 were taken at downstream manholes which are located at approximately 600 feet intervals.

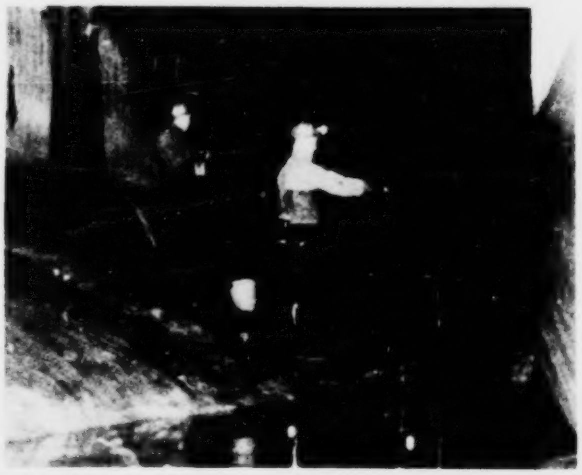


Figure 13 - 7 1/2 FEET SLUDGE BANK IN CONNER SEWER

Figure 15 - SAMPLE POINT IN SLUDGE DEPOSIT

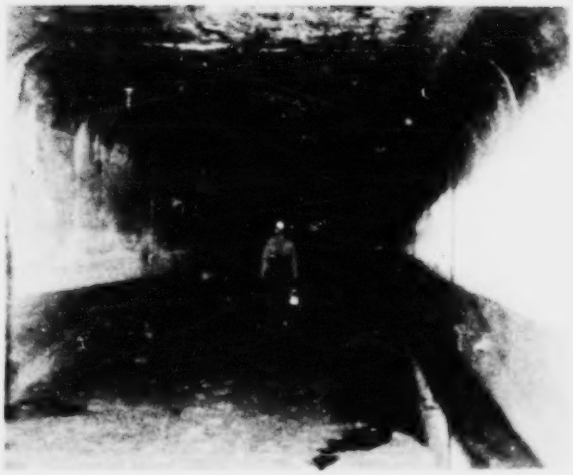


Figure 14 - EXTENT OF SLUDGE DEPOSITS

TABLE 2

SEWER DEPOSIT ANALYSIS

	% Passing Standard Sieve						
	Sieve Size						
Sample No.	3/8	4	10	20	50	100	% Organic
1	96.3	69.5	50.3	27.0	9.0	1.9	16.3
2	100.0	94.6	90.6	71.5	32.4	10.2	12.8
3	100.0	98.8	95.4	80.3	15.1	3.3	8.5
4	100.0	99.6	98.6	96.9	57.6	5.2	3.6
5	100.0	100.0	99.2	97.3	47.0	0.7	1.9
6	100.0	99.9	99.0	97.9	31.0	2.0	2.5
7	100.0	99.2	98.0	95.0	45.9	2.6	12.3
8	99.4	97.8	95.1	93.4	51.0	7.0	2.3

The deposits were a uniform gravelly sand with some organic material. Since the Conner Gravity Sewer is a combined sewer, this type of deposits is not unexpected.

HAZARDS OF IN-SYSTEM STORAGE

The closing of regulator gates on gravity sewers to effect storage poses no particular hazard since the backwater gates act as a built-in safety valve, but when storage is effected in low level barrels and their associated pumping station wet wells, there is a hazard to the system in the event of a sudden intense storm.

This possibility is illustrated on Figure 16 which shows a condition that has occurred at several of the storm pumping stations. Flow into the sewer from an intense storm tends to suddenly increase flow rates. This sudden increase in flow creates a translatory wave in the sewer (13, 14).

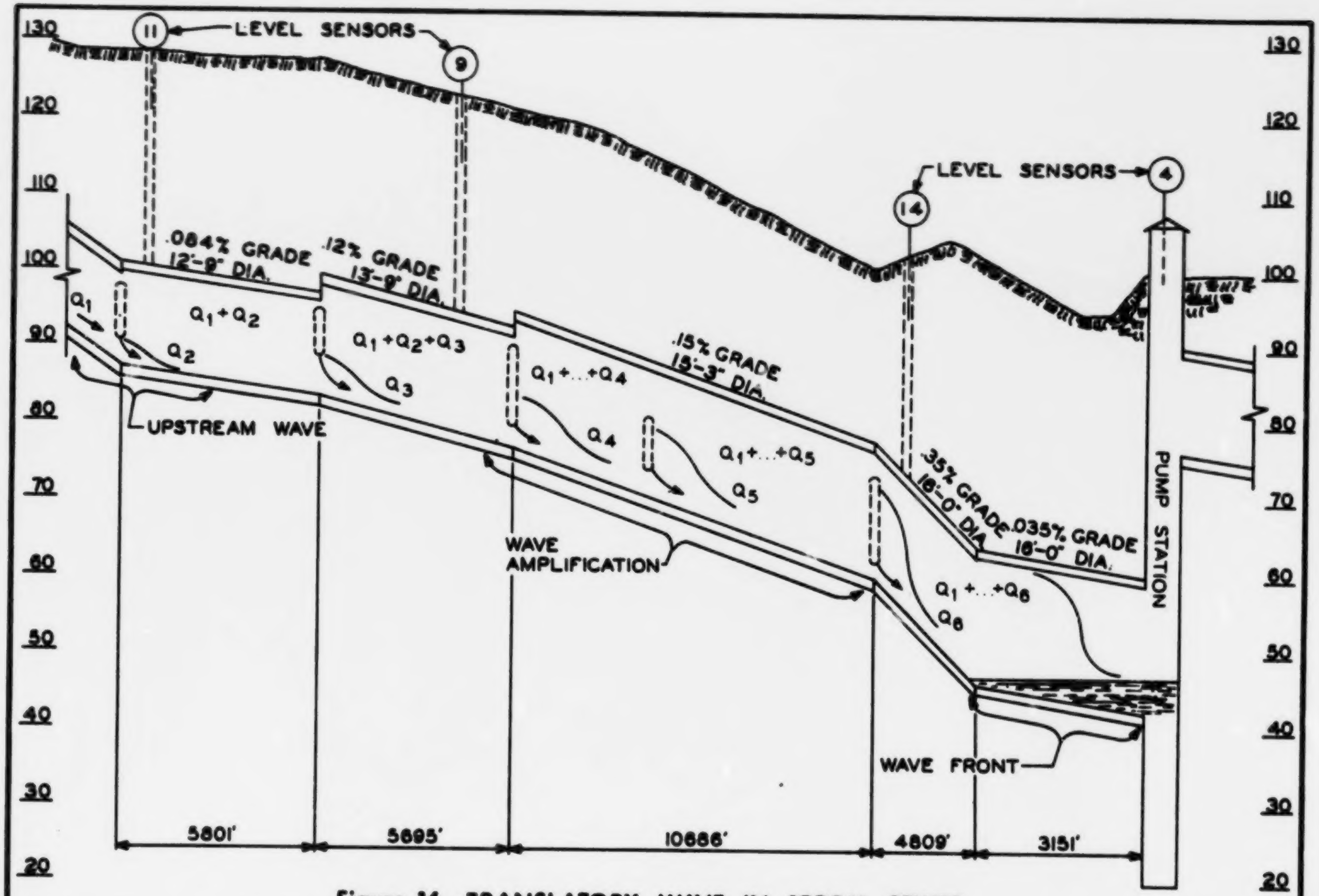


Figure 16 -TRANSLATORY WAVE IN STORM SEWER

As this wave travels down the sewer, it is amplified by further storm water inflows downstream. Thus, a rapid increase in flow can occur at the pump station. If the station has not been prepared to receive this flow, extensive flooding and lifting of manholes could result. The monitoring system should give the System Control Center enough lead time to enable the operators on duty to anticipate this surge.

SECTION V

CONCEPTS OF SEWER SYSTEM MONITORING AND REMOTE CONTROL

The basic concept of sewer system monitoring and remote control is the prevention of combined sewer overflows by using the existing storage capacity of the system to its full potential. By monitoring the levels in the sewer system, the status of the overflow points and the intensity of rainfall over the city, DMWD will have its first opportunity to discover what actually happens in the system as a rain storm moves across the city. The concept of actually operating a combined sewer system will now be possible since the Monitoring and Remote Control project will provide not only the data required to make decisions but it will also provide the means by which affirmative action can be taken to better utilize the full potential of the available storage. It no longer will be necessary to build a system and leave it buried underground, more or less forgotten until problems arise from overloading, sludge buildup or flooding.

SYSTEM OPERATION PRIOR TO MONITORING

The philosophy of operation prior to system monitoring was to prevent system backups and the resultant basement flooding. Storm wastewater pumpage to the receiving streams was considered to be less offensive than flooding. With the lack of upstream sewer level data and rainfall data, a method of operation which includes uncontrolled overflows and storm wastewater pumpage was the only possible alternative.

Although there was some degree of control at the pump stations, for the majority of the system consisting of gravity outfalls and float-controlled regulators or dams there was no control other than the manual regulator settings. In general the size of the regulator opening is proportional to the sewer size and as the sewers filled during storms, more flow was intercepted from the larger sewers than from smaller sewers. However, some of these major sewers are capable of storing large volumes before an overflow occurs while most of the smaller sewers are not. Thus, when the interceptor was filled to capacity, many of the smaller sewers which cannot store large volumes overflowed while storage capacity still existed in some major sewers. Thus, overflows occurred before the system was utilized to its capacity.

SYSTEM OPERATION WITH MONITORING

In order to operate a given system effectively, sufficient input data must be available to make decisions and output capability must be available to implement these decisions. With combined sewer systems, input data must include rainfall, levels of wastewater flow, and overflow status. This data would have to be displayed at a central location where the response of the total system could be analyzed and the appropriate decisions made. Output capability would include the controls necessary to implement the decisions with the reduction of combined sewer overflows as a goal.

System Operations

With each storm wastewater pumping station individually manned, at the advent of storm events the operator's only information upon which he could base a decision was the elevation of the station wet well. If the wet well elevation rose above a certain fixed point, the operator would turn on a storm pump. If the wet well elevation continued to rise, as many storm pumps as needed would be placed on line to reverse the rising wet well trend. Since the widespread flooding of basements was to be averted, the previous operating procedure dictated overflow pumpage whenever high volume flows occurred. Under this procedure an intense but short duration storm would cause pumpage to the river, even though the system as a whole was capable of containing the additional flow. This would occur solely because of a lack of information. With storm pumpage capabilities of up to 4,070 cfs per station, this could not be tolerated. In addition, with the wastewater pumping stations independently operated, the necessary system control approach needed to effectively operate the wastewater collection system would be unattainable. Thus the pumping stations, as shown in Table 3, were modified to allow remote control from a central location.

Storm Anticipation and First Flush Interception

The primary goal of completely containing the runoff from a rain storm should be largely achieved through storm anticipation technique. The most successful use of monitoring and remote control for combined sewer overflows should occur with either short duration storms or "spot cell" storms. As frequently happens during the summer months in the Detroit area, small, sometimes intense storm cells move across the city. With the telemetering rain gage data, the systems control operators should be able to follow the storm cell and apply an overflow control technique which would suit the system rather well.

The network of fourteen rain gages will provide the data from which the impact of a major storm can be anticipated. As the cell is picked up by one of the rain gages, the data logging equipment will change from the usual one-hour status printout cycle to a 15-minute and, if necessary, a 5-minute status printout cycle. The information received will indicate to the operators the intensity of the rain, the total amount of rainfall since the beginning of the rain, and the levels of the sewers in the area.

The four western gages are from three to seven miles west of the City of Detroit city limits since a majority of storms come from that direction. Depending on the speed of travel of the storm, this should give Systems Control Center from one to three hours of warning before actual runoff

TABLE 3

REMOTELY OPERATED PUMPS

Station	SANITARY PUMPS No.	CFS/ Pump	Total	STORM PUMPS No.	CFS/ Pump	Total
Bluehill	2	10	20	3	390	1170
Conner	2	115	230	NOTE: 8 @ 500 cfs not presently operated from the Systems Control Center		
	1	77	77			
	1	50	50			
	4		357			
Freud	0			2*	35	70
				8	500	4000
				10		4070
Fairview	1	75	75	0		
	3	150	450			
	4		525			
Oakwood	2	20	40	2	40	80
				2	98	196
				2	106	212
				6		488
Woodmere	2	8	16	3	283	849
Puritan	3	7	21			
TOTAL	17		979	22		6577

*Also used to dewater storage

into the sewer system occurs, and should allow DMWD to lower the hydraulic gradient of its system. In practice, the Systems Control Center would place in operation more sanitary wastewater pumps, either at all the pump stations or at selected pump stations, than is necessary during normal dry weather flow in order to draw down the respective tributary trunk sewers and force more flow to the Wastewater Treatment Plant. At the plant additional pumps will be placed in service until a minimum depth in the wet well can be maintained. This procedure should insure a maximum of unused capacity in the sewer system.

As runoff enters the system the DMWD would capture a greater percentage of the more grossly contaminated "first flush" portion of a rain storm by filling the unused volume in the sewer system caused by the system pumpdown (15). As the sewer system continues to accept runoff the unused volume will be exhausted and combined sewer overflows will occur. However, these overflows should be neither as contaminated nor as sustained as the overflows which occur before the use of the pumpdown procedure.

Selective Retention

Although remote operation of pump stations would allow system pumpdown and could provide some storage potential, the reduction of combined sewer overflows would not be effective without control of certain regulators. Under this demonstration project, four major regulators were selected for remote operation. Three of these regulators, the Hubbell-Southfield, the Baby Creek and the Conner Gravity, were selected because they control flow from three major districts and the sewers would provide large storage volumes. With control of these regulators, it would be possible to provide for in-system storage and interceptor relief. The fourth regulator, the Warren-Pierson, would allow protection from interceptor flooding along the upper Rouge River.

System Operation

When the concepts of storm anticipation, first flush interception and selective retention are combined to form a mode of operation, a workable procedure for controlling the Detroit wastewater collection system emerges. For example, if a thunderstorm approaches from the southwest (the normal weather pattern) rainfall would be picked up by one of the western telemetered rain gages and the data logger would initiate the 15-minute print cycle. Systems Control Center would immediately have extra pumps put on line at the Wastewater Treatment Plant in order to lower the hydraulic gradient of the system. As the storm moved into the tributary area, runoff would enter the Northwest Interceptor and the Hubbell-Southfield sewer system as shown in Figure 17. Systems Control Center would then close the regulator on the Hubbell-Southfield system to insure Northwest Interceptor capacity and utilize the 3.5 million gallons of storage in the Hubbell-Southfield sewer. Next, the Baby Creek regulator would be closed utilizing the 52 million gallons of storage within this system. While storage is being initiated in the

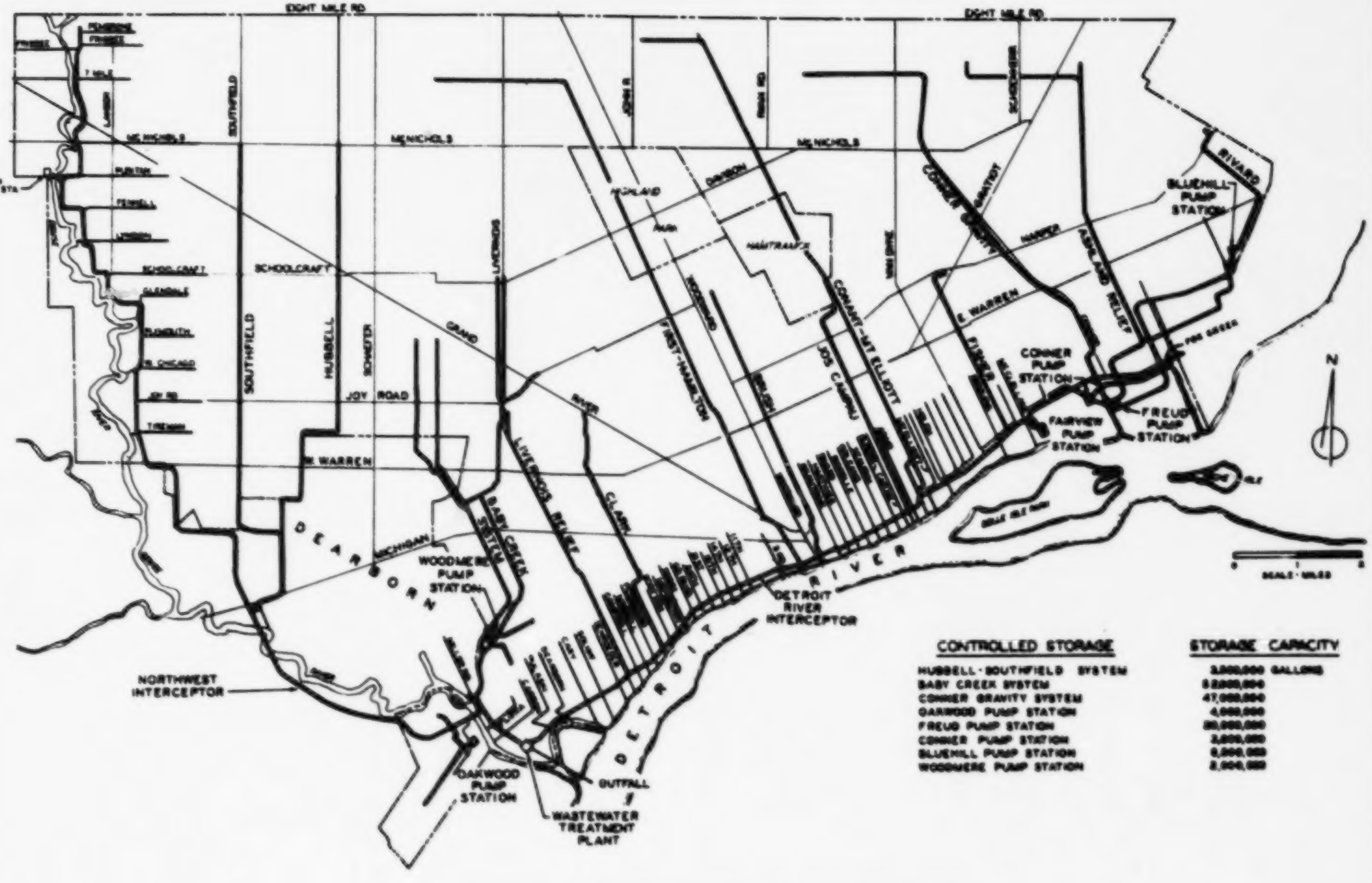


Figure 17 -MAJOR SEWERS IN THE DETROIT SYSTEM

western portions of the city, the east side is still being pumped down. As the storm moves across the city, runoff would start to enter the central portion of the system draining into the First-Hamilton and the Conant-Mt. Elliott sewers. By the time a thunderstorm is this far east the rain should have stopped falling on the west portion of the system and all runoff is stored. As the east side sewers fill, the Conner Creek regulator is closed to the interceptor and the resulting 47 million gallons of storage is used with an additional 20 million gallons of storm wastewater routed to the Freud Pumping Station system, where it is also stored. By this time the storm should have moved off over Lake St. Clair and the DMWD will start its dewatering procedure, dewatering on a west-to-east basis those sewers in which storage took place.

If by pumping down the sewer system in storm anticipation, it appears that a rain cannot be completely contained, an in-system storage and flow routing procedure would be initiated. With the judicious selection of station pumping and sluice gate positioning, it should be possible to back up the portions of the system which are not totally utilized and relieve the portions of the system which are at full capacity. This should be possible by "holding back" the sections of the city in which rain has ceased falling or by initiating a flow routing procedure to force flow from a sewer flowing full into a sewer flowing at less than maximum capacity.

Selective Overflowing

Combined sewer systems are designed to overflow during storm events and total capture of all runoff from a major storm is not possible using in-system storage techniques. However, by monitoring sewer levels and rainfall, it should be possible to cause overflows at points which will have the least impact on the receiving waters (16). At the same time, priority would be given for the capture of the more heavily polluted wastewater. In addition, regulators could be adjusted to accept more flow from the sewers which carry the more heavily polluted wastewaters.

The Warren-Pierson Regulator was remotely controlled to apply the concept of selective overflowing. With increased urbanization of the Upper Rouge River basin, the river now crests at higher elevations (17). This has caused backflow of river water into several unprotected outfalls along the river. As an interim measure until backwater gates could be installed, the Warren-Pierson Regulator would be closed when river level sensors indicated levels high enough to cause flow into the system above this point. This operation would serve to protect the interceptor downstream of the regulator.

CONNER FLUSHING GATES

Figure 18 illustrates the geometery of the Conner Gravity Sewer at the transition from a two-barrel 12'-0" x 16'-0" box to a three-barrel

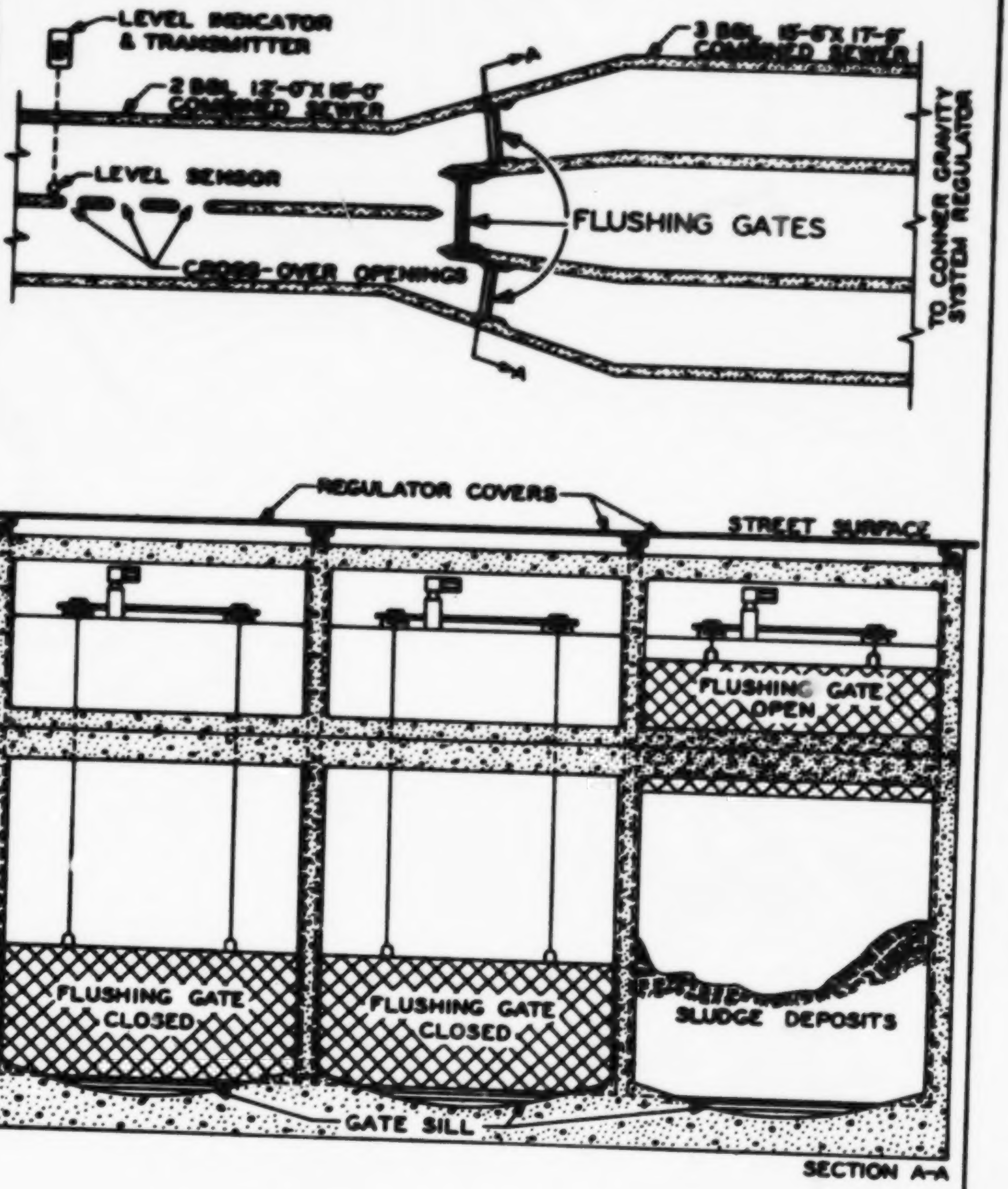


Figure 18-FLUSHING GATE INSTALLATION

15'-6" x 17'-9" box. Since sedimentation problems had occurred and since sludge, sand and gravel deposits were blocking a portion of the Conner Gravity barrels where in-system storage was desirable, the concept of using dry weather flow to flush out a sewer following storage was included in the project. The plan was to attempt to dislodge the existing deposits and evaluate whether this concept could be used to keep this and other multi-barrel sewers clean in the future.

During normal dry weather flow, two of the gates would be lowered and the flow forced through the remaining barrel. Initially the flushing of the east and west barrels would be for short periods in order to avoid overloading the grit chamber and primary sedimentation tanks at the Wastewater Treatment Plant. As the deposits were removed, it was planned to flush each barrel routinely for a four-hour period. For storms, however, all the gates would be raised to insure that upstream flooding did not occur. As the system was dewatered and the level upstream of the gates was less than seven feet, two of the gates would be lowered and the flushing procedure initiated.

SYSTEM SURVEILLANCE

Among the 76 overflow points are 45 float-controlled regulators. Prior to the monitoring system one of the routine maintenance programs was to check each regulator and backwater gate once a week (10, 18). Thus, if the regulator malfunctioned, it was possible to overflow sanitary sewage to the rivers without knowing it for a period of days. The advent of the monitoring system now would give the DMWD a 24-hour surveillance capability. If a backwater gate is open, an overflow weir is being topped, or if a gate does not close properly, a maintenance crew could be sent out to rectify the situation immediately. Specifically, the DMWD would be able to discover gates which are jammed open, regulator malfunctions and sewers clogged with debris solely through the surveillance aspect of the overflow monitoring portion of the system. It is felt that these overflow eliminations would be particularly significant because these would be overflows of strictly sanitary sewage and therefore grossly polluted (10, 19, 22).

SECTION VI

MONITORING AND REMOTE CONTROL EQUIPMENT

In order to implement the conceptual mode of operation, a real-time, sensor based, data acquisition system was installed to provide data on interceptor, combined sewer and pump station wet well levels, rainfall intensity and total, and the status of overflow points. In addition, a supervisory control system, independent of the data acquisition system, was installed to provide for remote control of pump stations and regulators and to display pump status, regulator operation, wet well levels and scanner alarms.

Sensor data is telemetered to the Systems Control Center in the Water Board Building, which is located in downtown Detroit. The telemetered signals are interfaced with a digital computer which processes the data and supervises output to three data logging typewriters. Pre-programmed alarms are printed on a teletype unit which also may be used for programming. Pump station wet well levels are interfaced with both the computer system and the supervisory control system to provide a backup in the event of failure of either system. Table 4 lists the equipment that was installed under this demonstration project. The rain gages, level sensors, proximity sensors, electrode sensors, audio tone transmitters and receivers, and the computer and output devices comprise the monitoring system. The remaining equipment listed is part of the remote control system.

RAIN GAGES

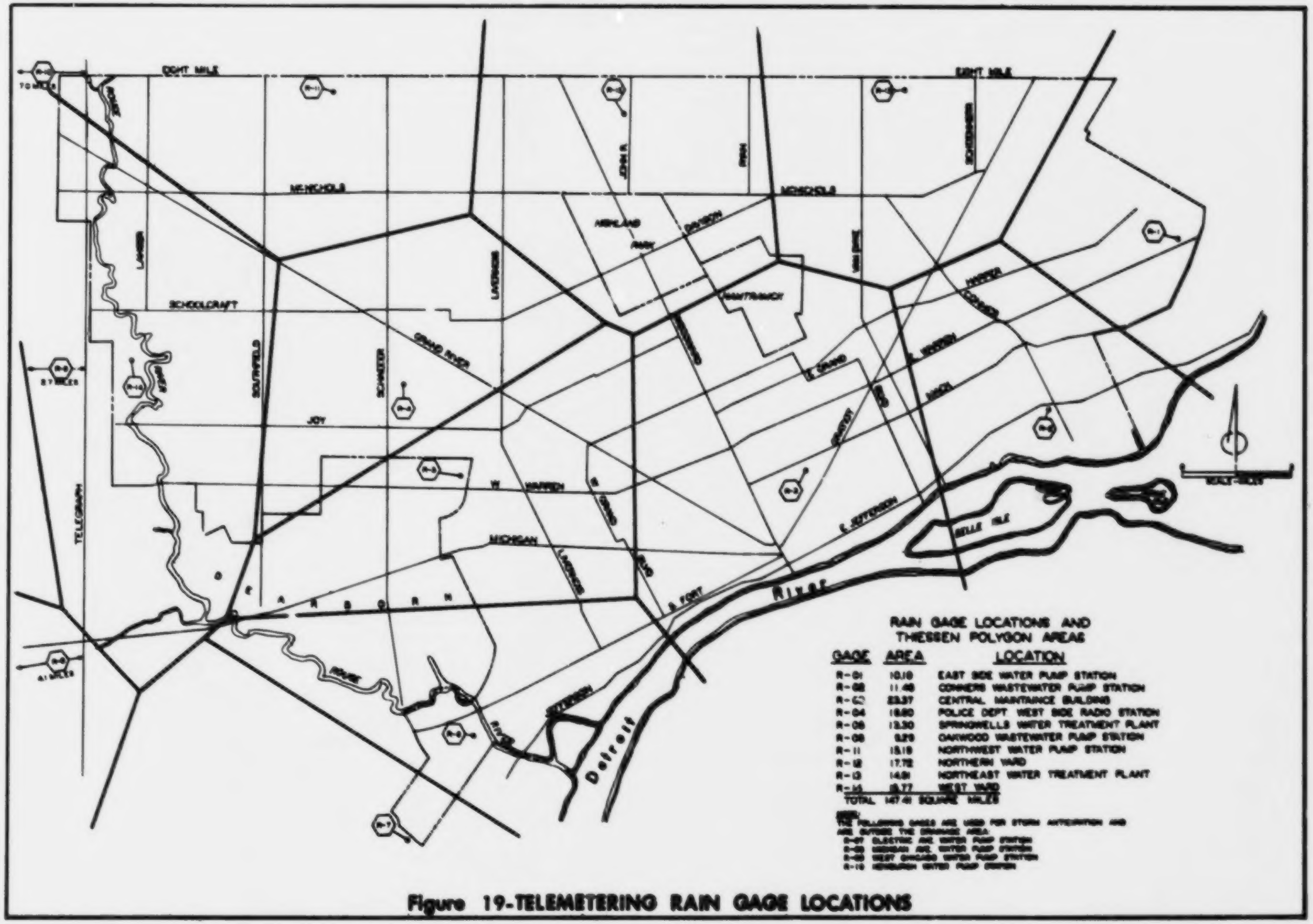
The fourteen tipping bucket rain gages were installed at the locations shown on Figure 19. Because these gages require both power and communication links, and because ready access was to be maintained, the gages were located on municipal buildings rather than private buildings. Wherever possible, DMWD buildings were used. Ideally the gages should be placed at ground level but, because of the desire to keep the gages away from various types of outside interference, it was decided to place the instruments on the top of large, flat roofs. A typical installation is pictured in Figure 20. It was felt that placing the gages on a flat roof would not subject them to unnatural air currents and that the inaccuracy caused by rainfall being blown into the gage would not occur. However, finding a public building with a large, flat roof in a desired area became difficult. From an examination of Figure 19 it is evident that the gages could have had a better distribution (20).

The gage consists of a funnel, the large end of which is open to the environment, which collects rainfall and drains into a triangular shaped bucket. There are two of these buckets placed so that as one of the buckets fill, the weight of the collected rainfall causes the bucket to tip, emptying it and placing the other bucket in position. The rainfall

TABLE 4

MONITORING AND REMOTE CONTROL EQUIPMENT

Number	Type	Supplier
14	Tipping Bucket Rain Gage	Belfort Instrument Company Baltimore, Maryland
118	Level Sensors with Level Transmitter	Bristol Company Glen Cove, New York
30	Proximity Sensors with Amplifier	Minneapolis-Honeywell
38	Electrode Sensors with Amplifier	B/W Controller Corp. Birmingham, Michigan
200	Audio Tone Transmitters and Receivers	Quindar Electronics, Inc. Springfield, New Jersey
1	PDP8 Digital Computer (4K Core and 32K Disc) with Operator's Console	Bristol Company
3	Data Logging Typewriters with 30-inch Platens	I.B.M. Corporation
1	Teletype	Teletype Corporation Skokie, Illinois
13	Sets of Transmitters, Receivers, Contact Scanners and Related Equipment for Remote Control of Pump Stations and Regulators Mounted in Three Control Panels	Quindar Electronics
18	Strip Chart Recorders	Bristol Company
6	Limitorque Operators	Philadelphia Gear Corp.
5	Gates (3 roller, 2 sluice)	Rodney Hunt



RAIN GAGE LOCATIONS AND
THIESSEN POLYGON AREAS

GAGE	AREA	LOCATION
R-01	10.10	EAST SIDE WATER PUMP STATION
R-02	11.40	CONNERS WASTEWATER PUMP STATION
R-03	23.37	CENTRAL MAINTAINCE BUILDING
R-04	16.80	POLICE DEPT WEST SIDE RADIO STATION
R-05	13.30	SPRINGWELLS WATER TREATMENT PLANT
R-06	9.29	OAKWOOD WASTEWATER PUMP STATION
R-11	15.19	NORTHWEST WATER PUMP STATION
R-12	17.72	NORTHERN YARD
R-13	14.91	NORTHEAST WATER TREATMENT PLANT
R-14	15.77	WEST YARD
TOTAL	147.41	SQUARE MILES

NOTE:
THE FOLLOWING GAGES ARE USED FOR STORM ANTICIPATION AND ARE OUTSIDE THE DRAINAGE AREA.
R-07 ELECTRIC AVE WATER PUMP STATION
R-08 MICHIGAN AVE. WATER PUMP STATION
R-09 WEST CHICAGO WATER PUMP STATION
R-10 [illegible] WATER PUMP STATION

Figure 19-TELEMETERING RAIN GAGE LOCATIONS

spilled from the first bucket drains out of the gage, eliminating the need for an observer.

The gages are equipped with mercury switches which momentarily interrupt a continuously telemetered signal each time the bucket tips. Each signal interruption is interpreted as 0.01 inch of rainfall by the computer. Figure 21 is a picture of the tipping bucket rain gage mechanism. The mercury switch is in the foreground of the opening and the actual tipping bucket is located directly behind the mercury switch.

Because snowfall is common during the winter months, some of the gages had electrical heating tapes wound around the outside of the funnel as shown in Figure 22. It was believed that the tapes would develop enough heat to cause the snowfall to melt and yield an accurate precipitation measurement.

Several tipping bucket gages were placed next to existing weighing type rain gages. The weighing gages are part of the Southeastern Michigan Rain Gage Network. The close proximity of the two types of gages has allowed an evaluation of the data obtained from the tipping bucket gages to be made.

LEVEL SENSORS

A total of 118 level sensors were installed at various points in the interceptors, the trunk line sewers ten feet in diameter or larger, certain critical smaller upstream sewers and in the wet wells of all pump stations as shown in Figure 23. Figure 24 shows the detail of a level sensor cell. Acting as a pressure cell, it consists of a 2-inch ID polyvinyl chloride tube approximately 11 inches long. This particular cell size was chosen in order to keep the volume of air in the cell at least ten times the volume of air in the 1/4-inch tubing. This ratio was believed sufficient to prevent wastewater from entering the tubing and possibly causing plugging. Figure 24 indicates the level of water in the cell under various conditions.

The cell is slanted about 15° downstream to help prevent fouling with debris. A continuous section of 1/4-inch OD nylon tube is attached to the cell and runs to the pedestal box as shown on the installation details in Figure 25. The tubing is protected by a 3/4-inch metallic conduit which runs from the top of the manhole to the pedestal base. At locations where manholes were located in a street, it was necessary to cut a slot approximately three inches deep in the pavement. After installation of the conduit and tubing the slot was filled with either hot asphalt or epoxy concrete to provide for a minimum of traffic interference. Figure 26 shows a typical level sensor pedestal and slot cut in the pavement. Both 120 VAC electrical service and leased communication lines enter the pedestal through underground conduits from service drops on utility poles as shown in Figure 27, if underground service is not available.

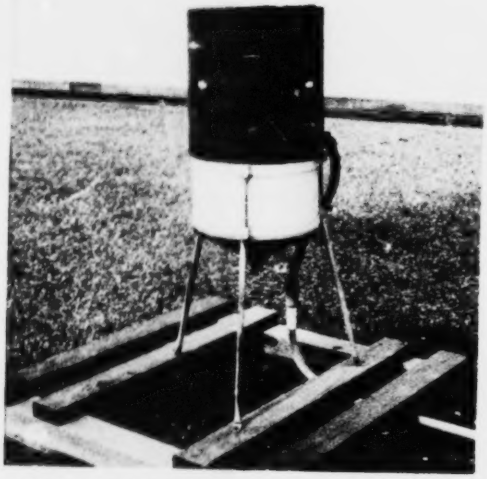


Figure 20 - TYPICAL RAIN GAGE INSTALLATION

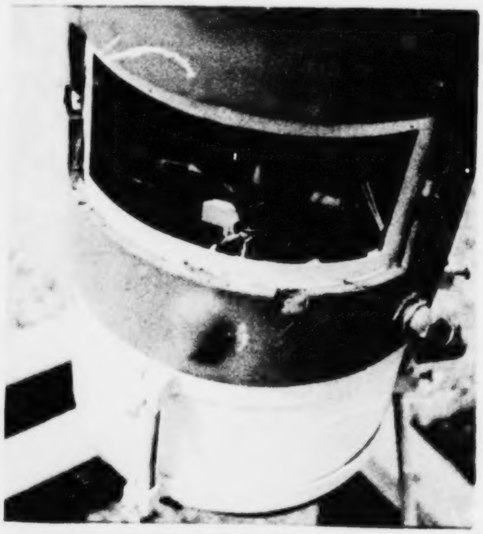


Figure 21 - TIPPING BUCKET MECHANISM

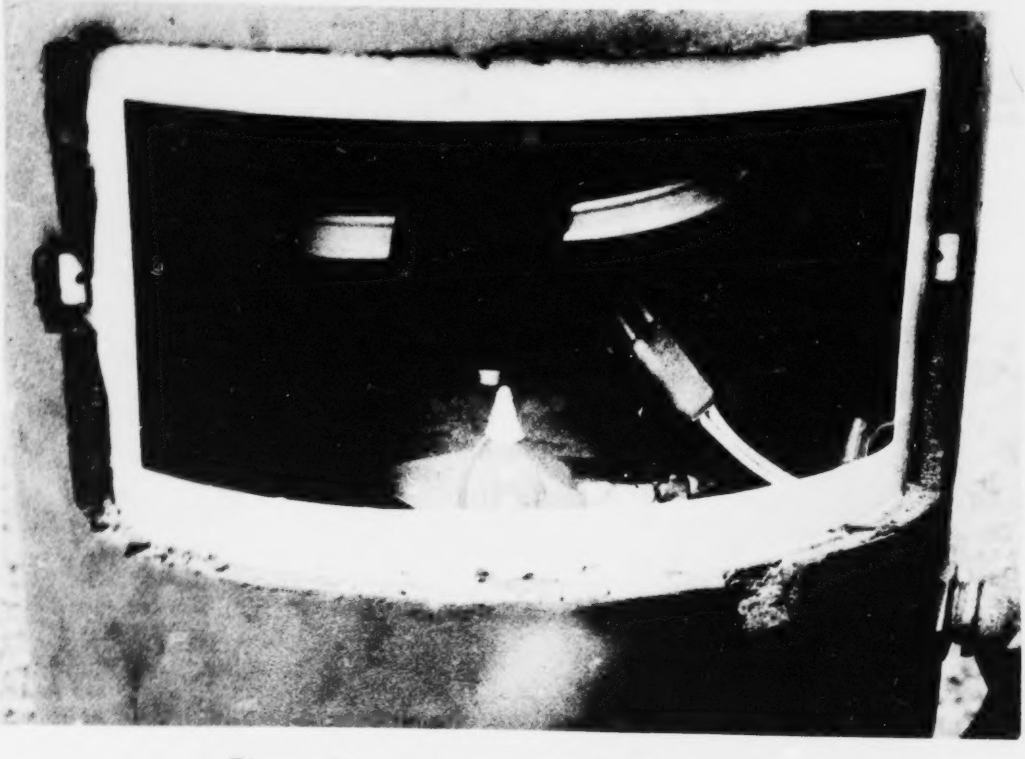


Figure 22 - HEATING TAPE INSTALLATION

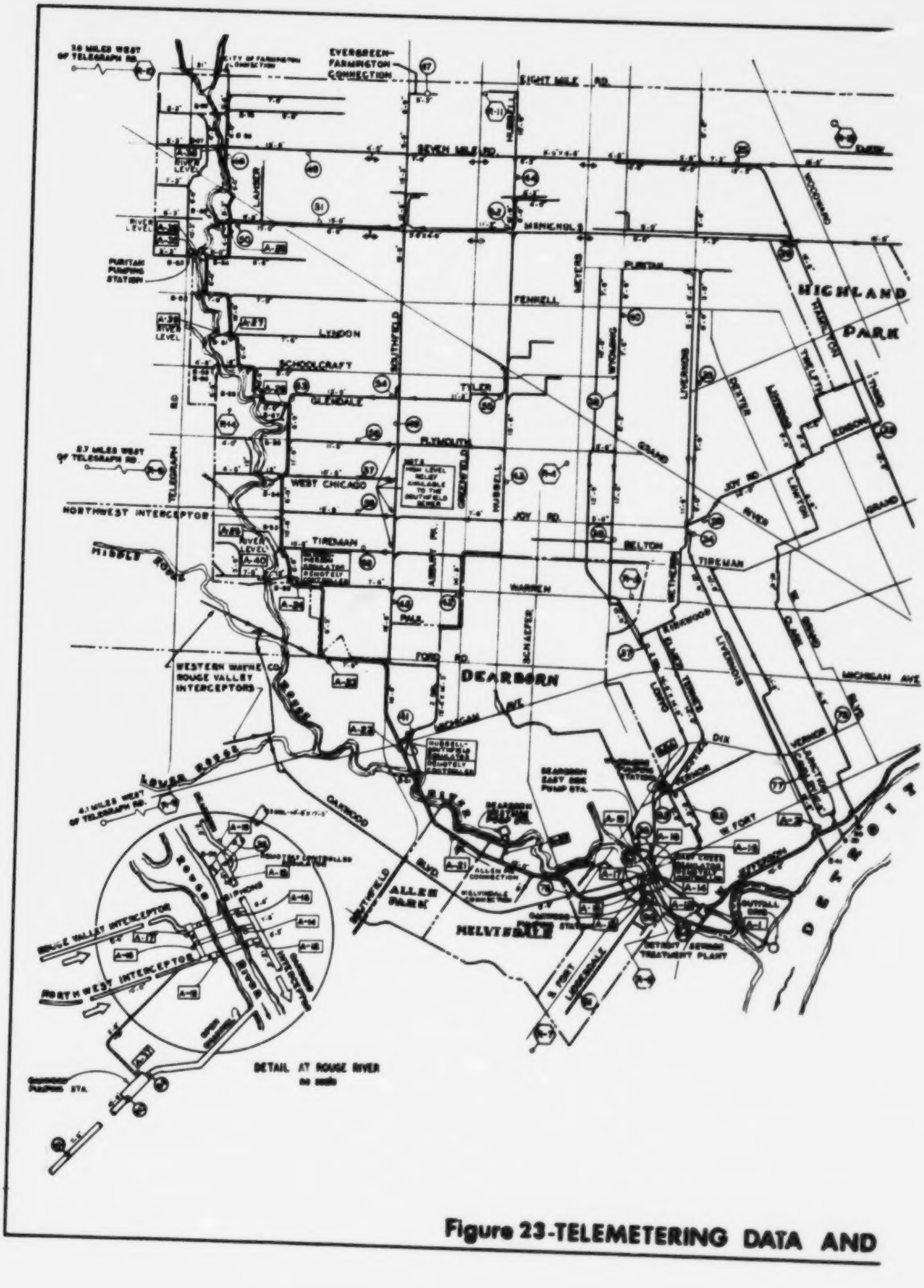
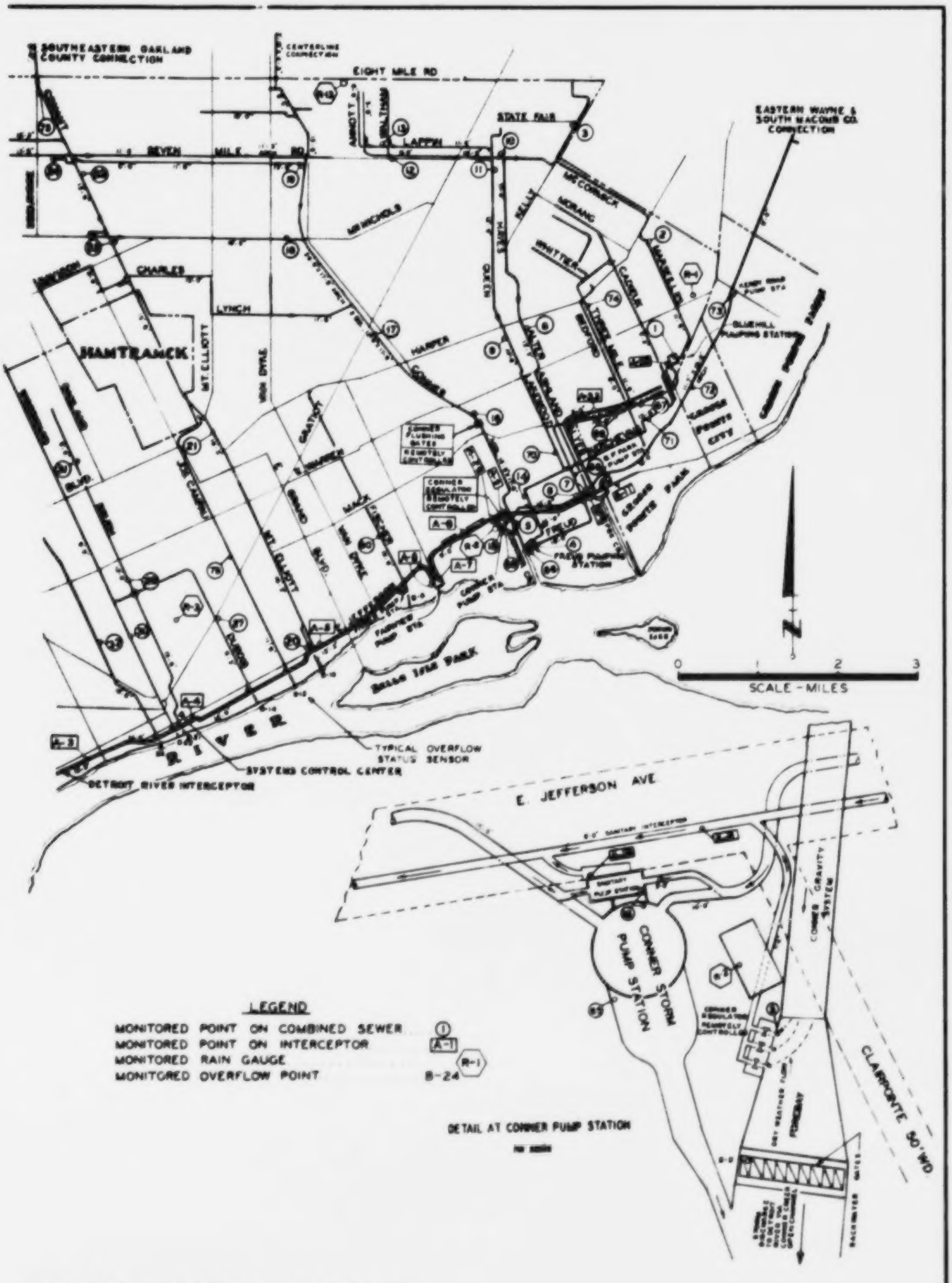
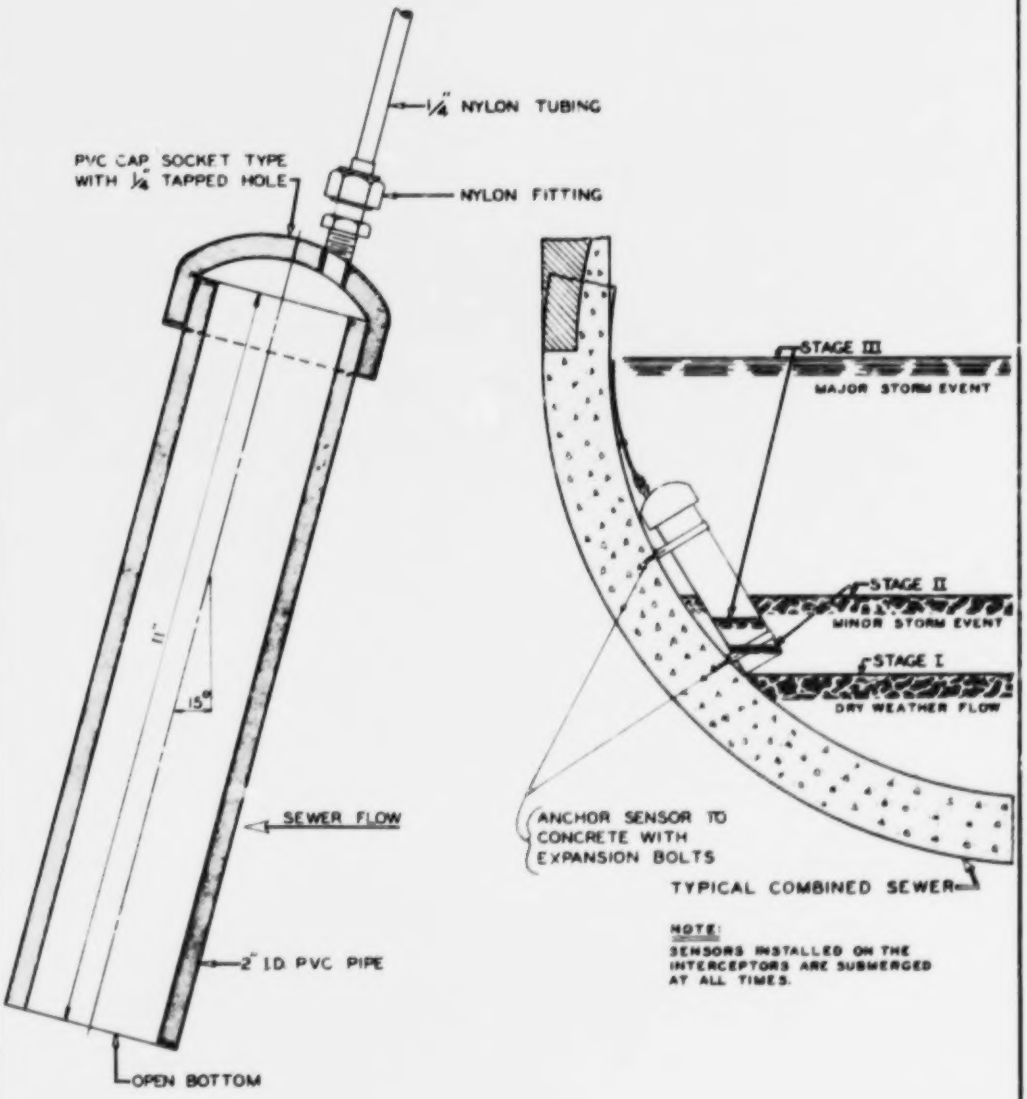


Figure 23-TELEMETERING DATA AND

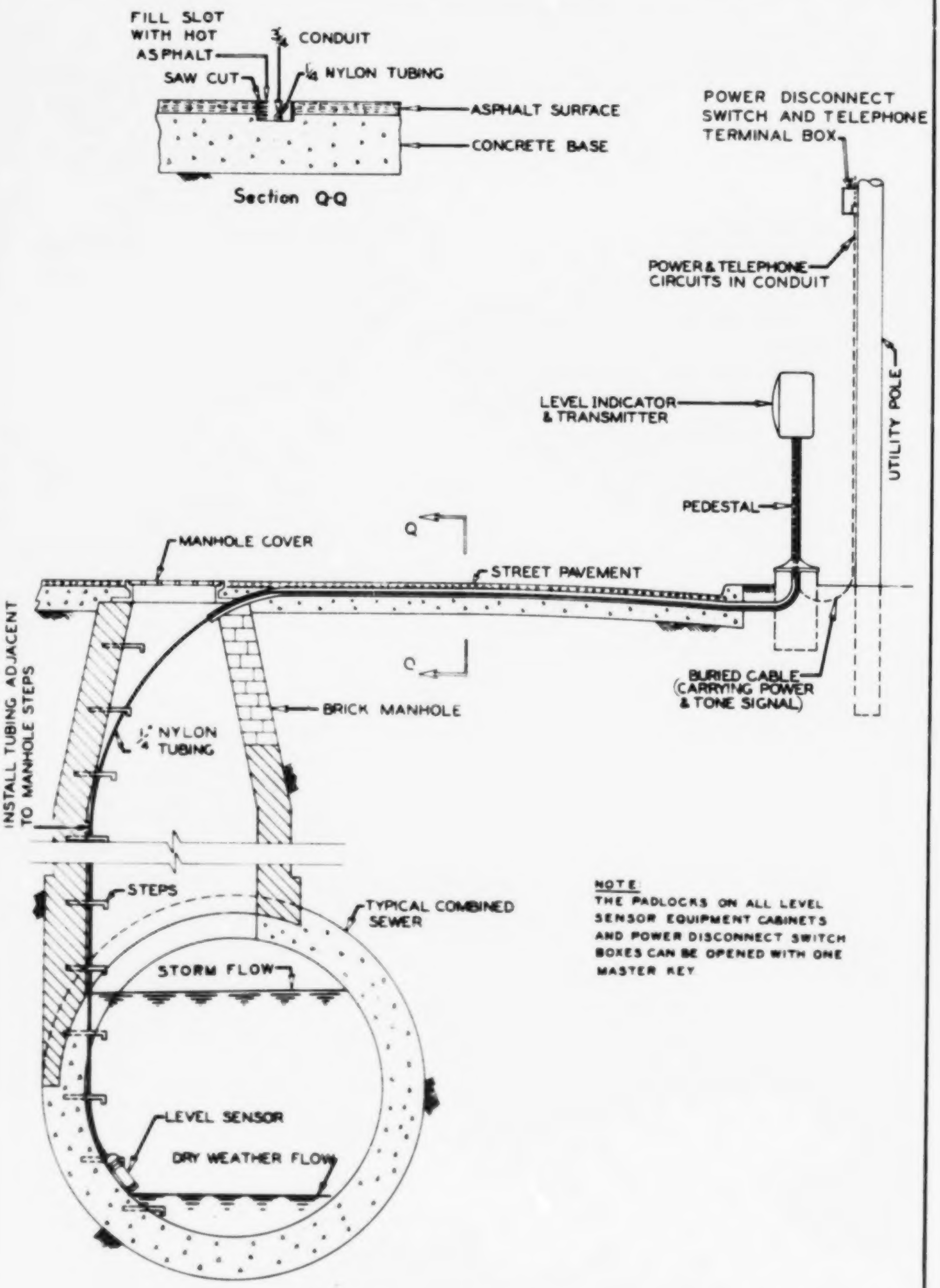


REMOTE CONTROL LOCATIONS



NOTE:
SENSORS INSTALLED ON THE INTERCEPTORS ARE SUBMERGED AT ALL TIMES.

Figure 24 - DETAIL OF LEVEL SENSOR CELL


FILL SLOT WITH HOT ASPHALT
SAW CUT
3/4 CONDUIT
1/4 NYLON TUBING
ASPHALT SURFACE
CONCRETE BASE
Section Q-Q
POWER DISCONNECT SWITCH AND TELEPHONE TERMINAL BOX
POWER & TELEPHONE CIRCUITS IN CONDUIT
UTILITY POLE
LEVEL INDICATOR & TRANSMITTER
PEDESTAL
Q
Q
MANHOLE COVER
STREET PAVEMENT
INSTALL TUBING ADJACENT TO MANHOLE STEPS
BRICK MANHOLE
1/4" NYLON TUBING
BURIED CABLE (CARRYING POWER & TONE SIGNAL)
STEPS
TYPICAL COMBINED SEWER
STORM FLOW
LEVEL SENSOR
DRY WEATHER FLOW

NOTE:
THE PADLOCKS ON ALL LEVEL SENSOR EQUIPMENT CABINETS AND POWER DISCONNECT SWITCH BOXES CAN BE OPENED WITH ONE MASTER KEY

Figure 25 - LEVEL SENSOR INSTALLATION

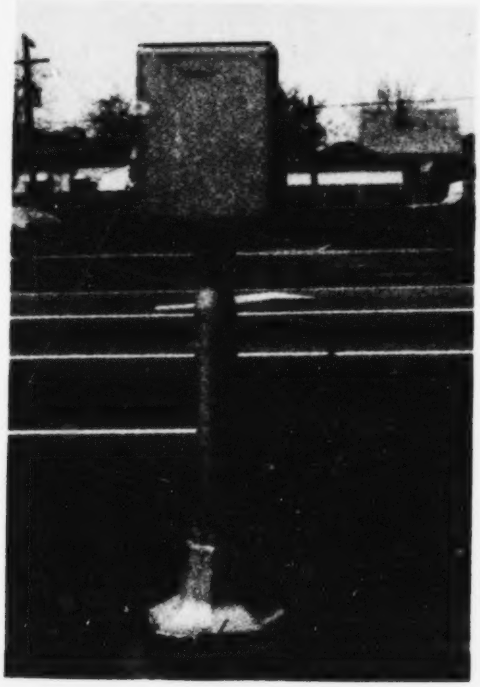


Figure 26 - LEVEL SENSOR PEDESTAL

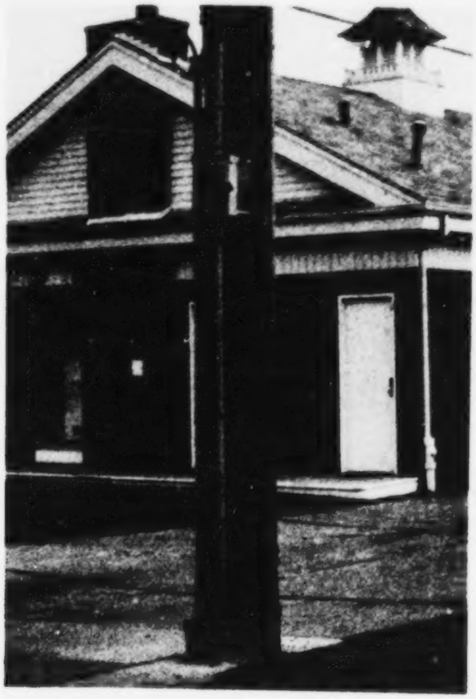


Figure 27 - SERVICE DROP

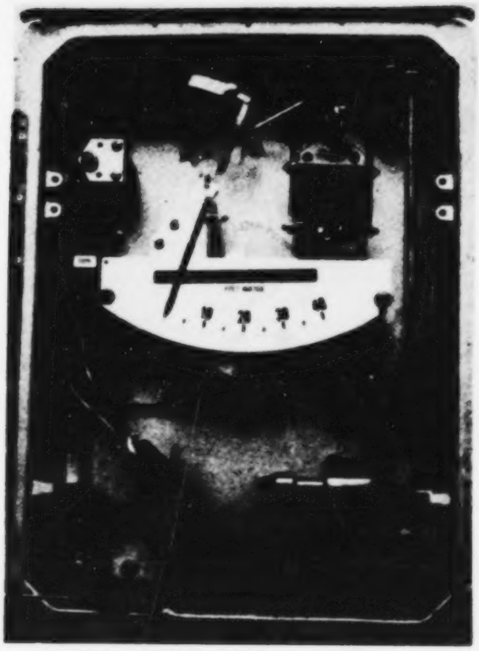


Figure 28 - INSIDE OF PEDESTAL CABINET

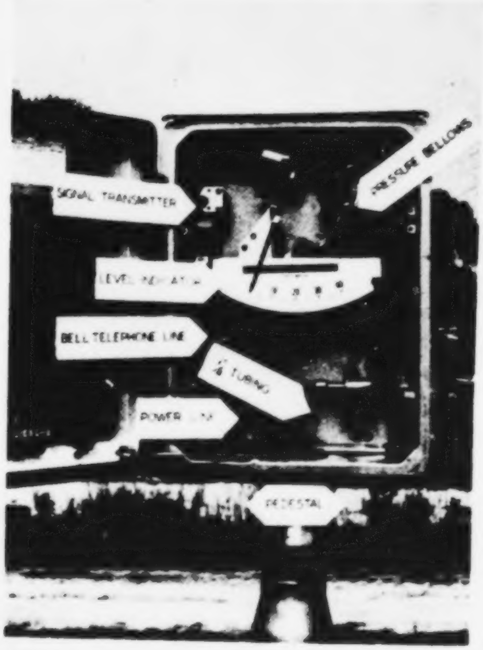


Figure 29 - LEVEL TRANSMISSION EQUIPMENT

Referring to Figure 28 and 29, as the wastewater level rises, air pressure in the level cell increases. This pressure increase is converted to a mechanical motion through the bellows, located in the upper right corner of the cabinet. Mechanical linkage attached to the bellows moves the level indicator arm to provide for on-site level readout. In addition, this linkage positions an arm on a cam which rotates at 12 rpm. The arm linkage and cam are designed so that contact is always made for the first second of the cycle. In the next three seconds contact is made for a time proportional to depth; i.e., zero seconds represent a zero depth and three seconds represents 40-foot depth (full scale). In the last second of the cycle no contact is made. The cam and cam motor and arm are located directly behind the level scale in the center of the cabinet. A tone signal is transmitted whenever the cam and arm are in contact.

OVERFLOW STATUS SENSORS

In order to study the frequency and duration of combined sewer overflows status sensors were installed at all major overflow points. These sensors are designed to transmit an interrupt signal to the data acquisition system which the computer interprets as an overflow. Sketches of each of these overflow points are shown in Figure 30. For a general location of each of these points, refer to Figure 23. It can be seen that at slightly more than half of the overflow points, dams are used to divert dry weather flow into the interceptor and prevent river water intrusion into the system. At the remaining locations, backwater gates prevent river water intrusion. The two types of sensors installed to detect overflows were proximity sensors and electrode sensors. Wherever possible, proximity sensors were installed to detect backwater gate openings. At locations with dams, electrode type sensors were installed.

Proximity Sensors

Proximity sensors are devices which detect the presence of a ferrous metal. The sensors are mounted within the sewer outfall at the backwater gate. A typical installation is detailed in Figure 31. For a timber gate, a block of ferrous metal is attached to the gate with the sensor directly facing the metal block. The sensitivity of the sensor is adjustable, but the normal distance between the sensor and the metal block is approximately 1/2-inch. A continuous signal is maintained when the backwater gate is in the closed prosition. As the backwater gate opens, the distance between the sensor and the metal block increases to a point at which the sensor no longer emits a signal. This in turn causes a relay to open at the equipment pedestal. When the delay opens the tone signal is no longer transmitted to the data acquisition center and a gate opening is logged.

Electrode Sensors

At dams, as shown on Figure 32, a two-element electrode probe is anchored upstream of the dam. The electrodes are positioned so that there is a

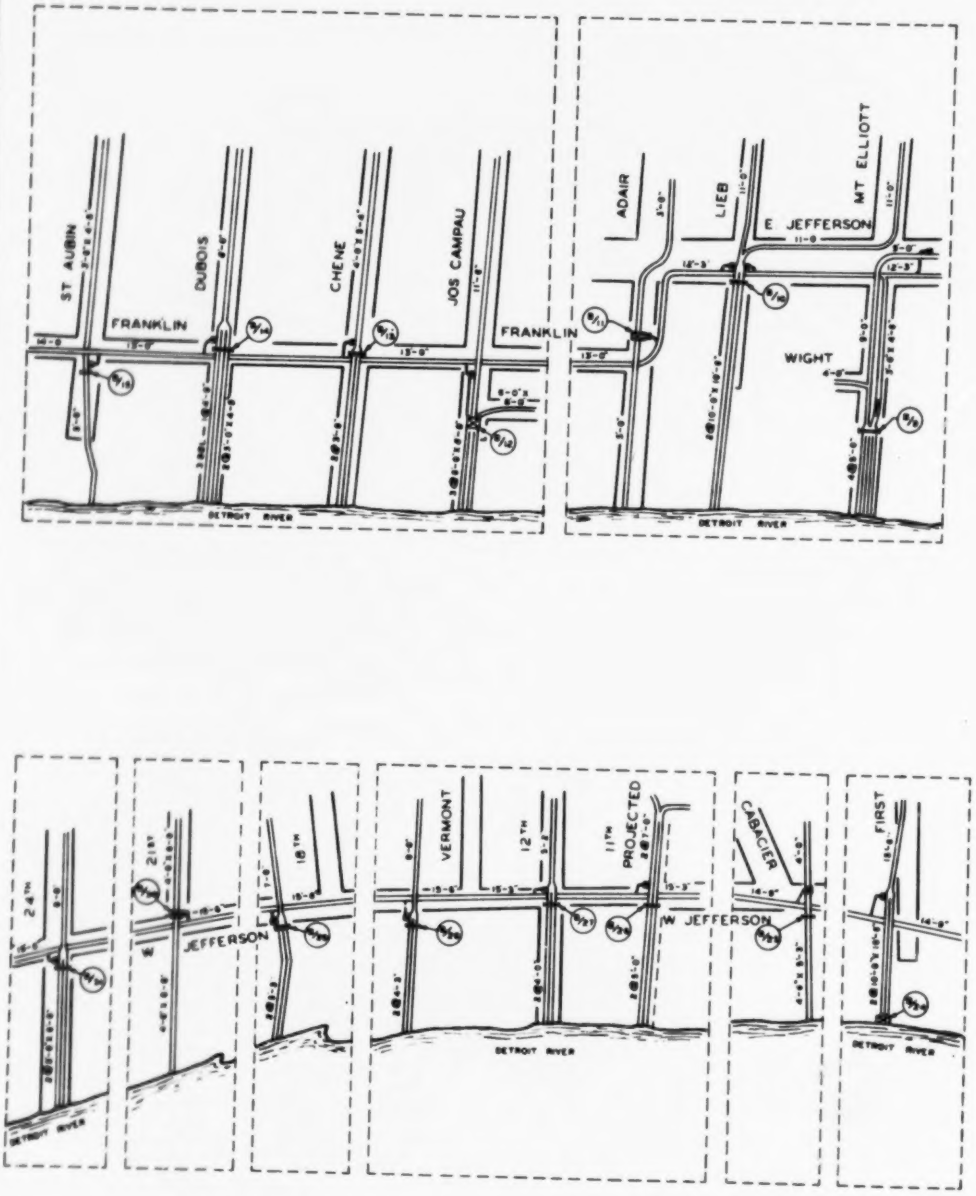
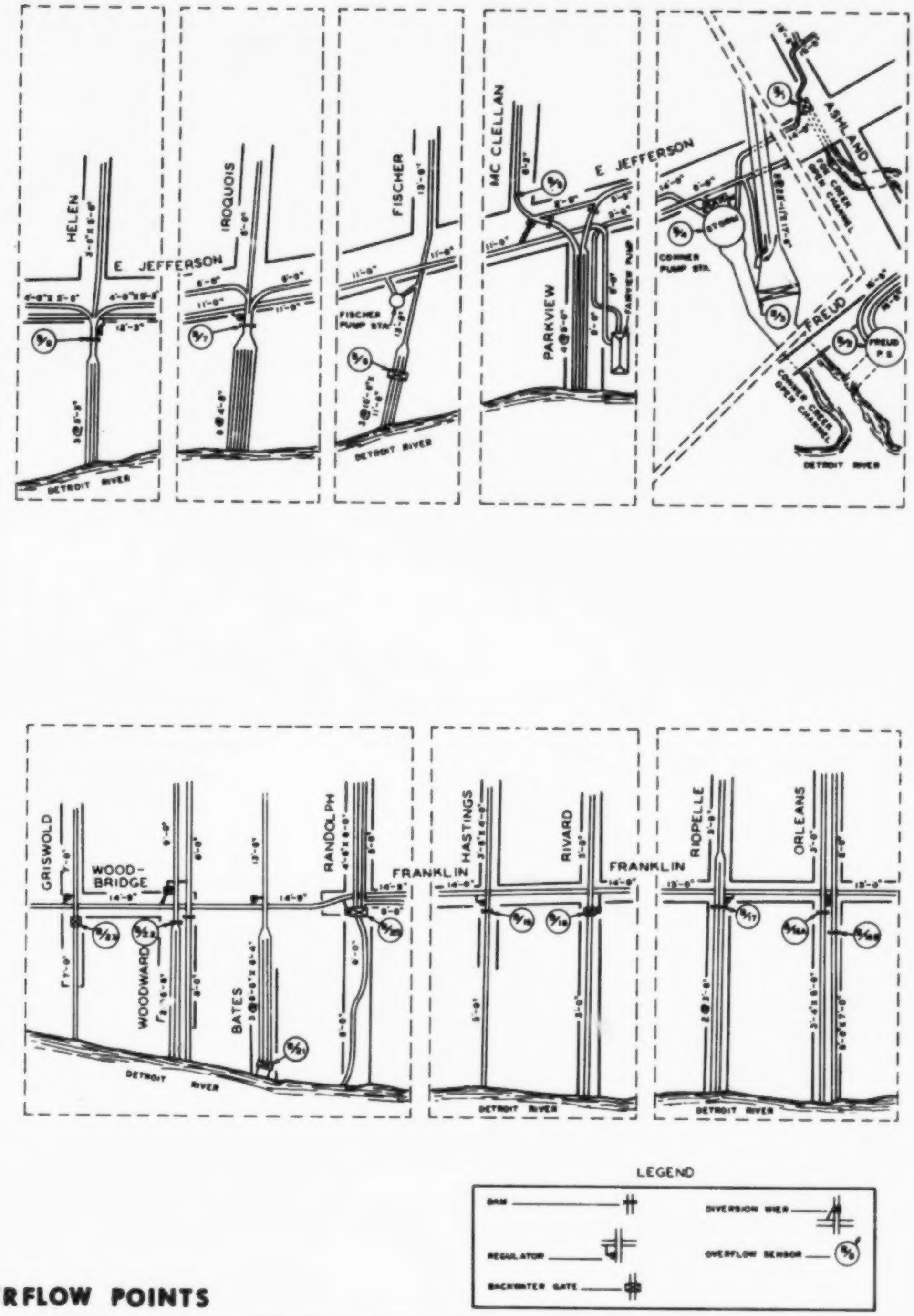


Figure 30-MONITORED



OVERFLOW POINTS

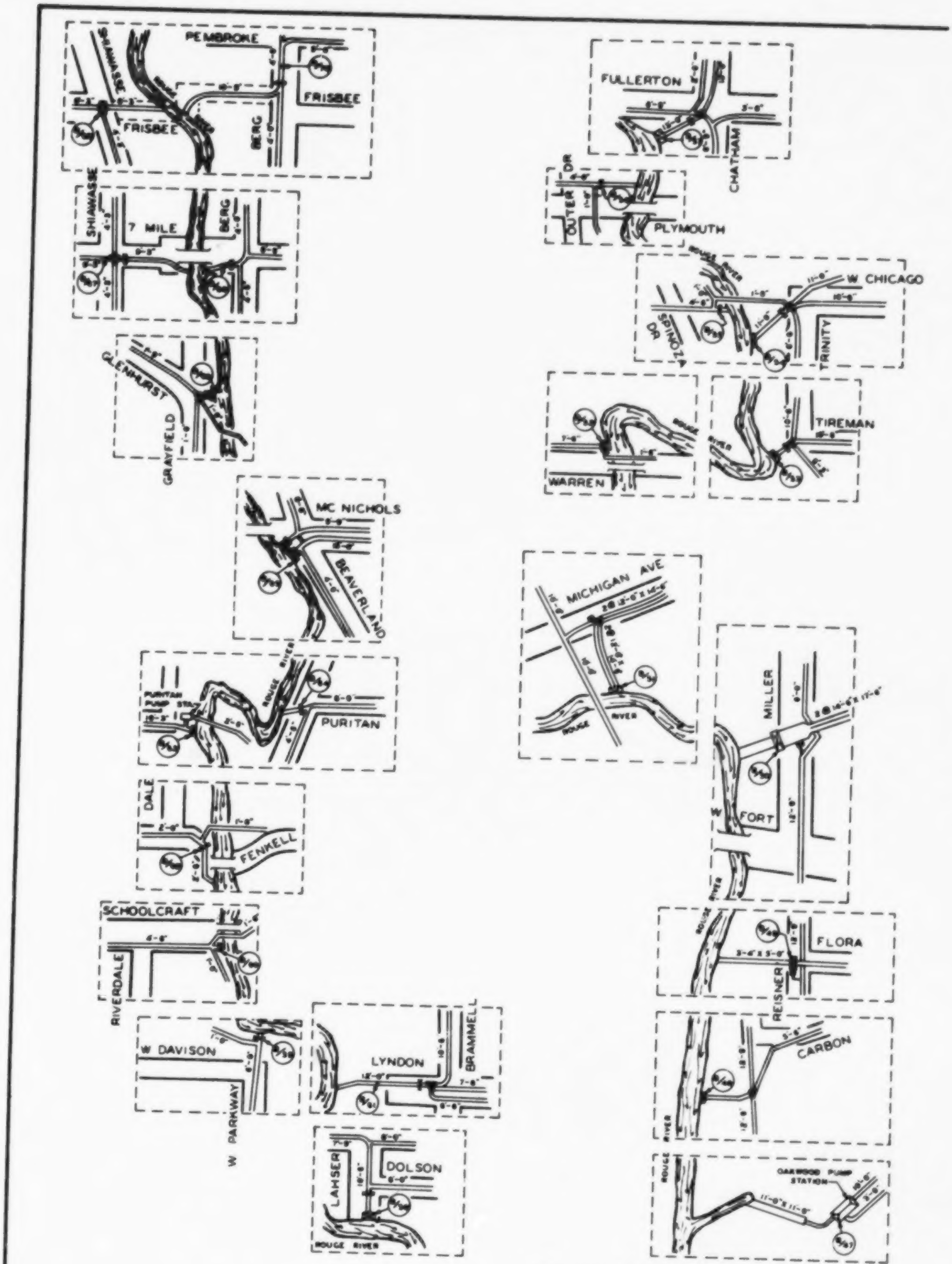
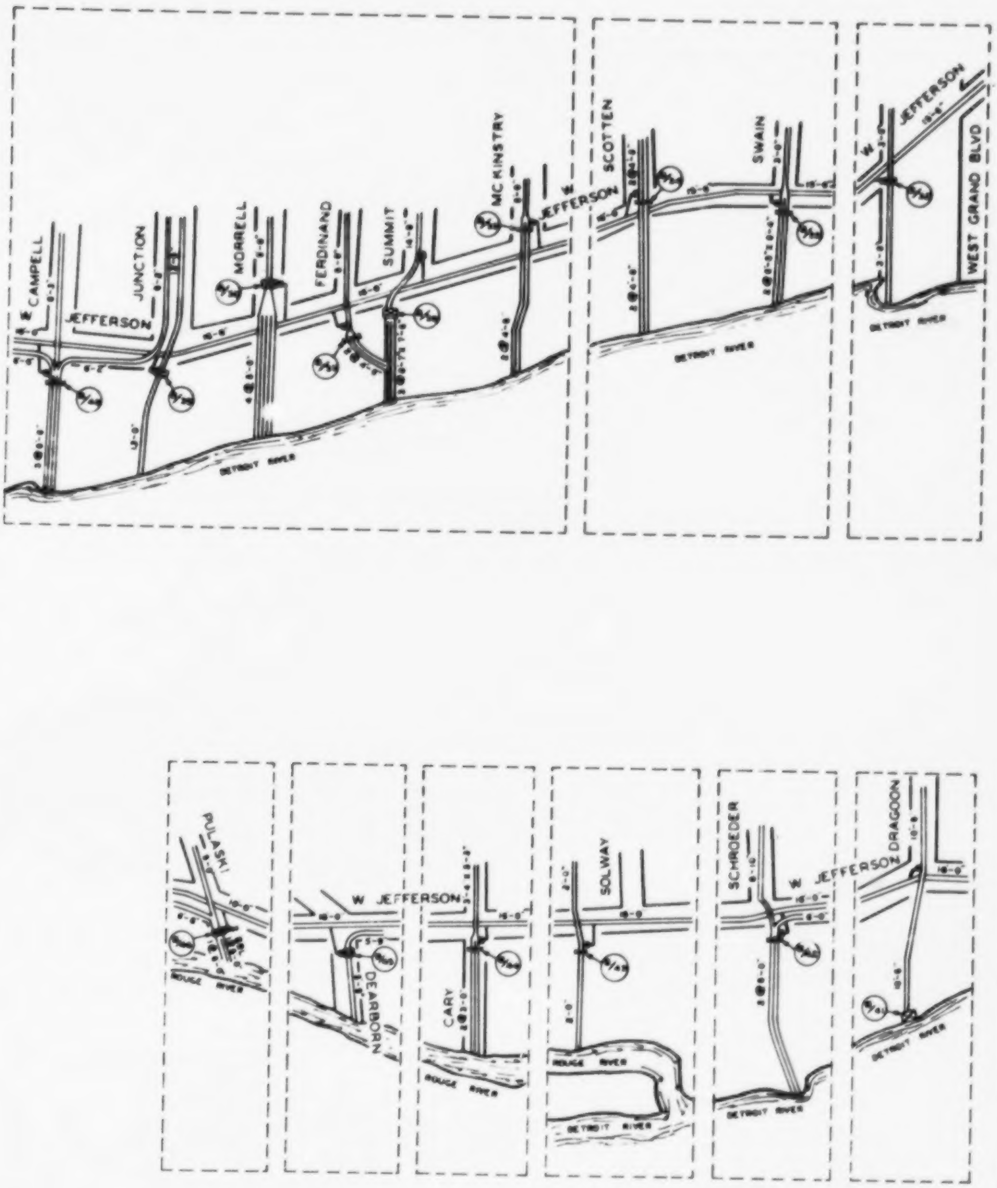


Figure 30-MONITORED OVER-



FLOW POINTS (CONT.)

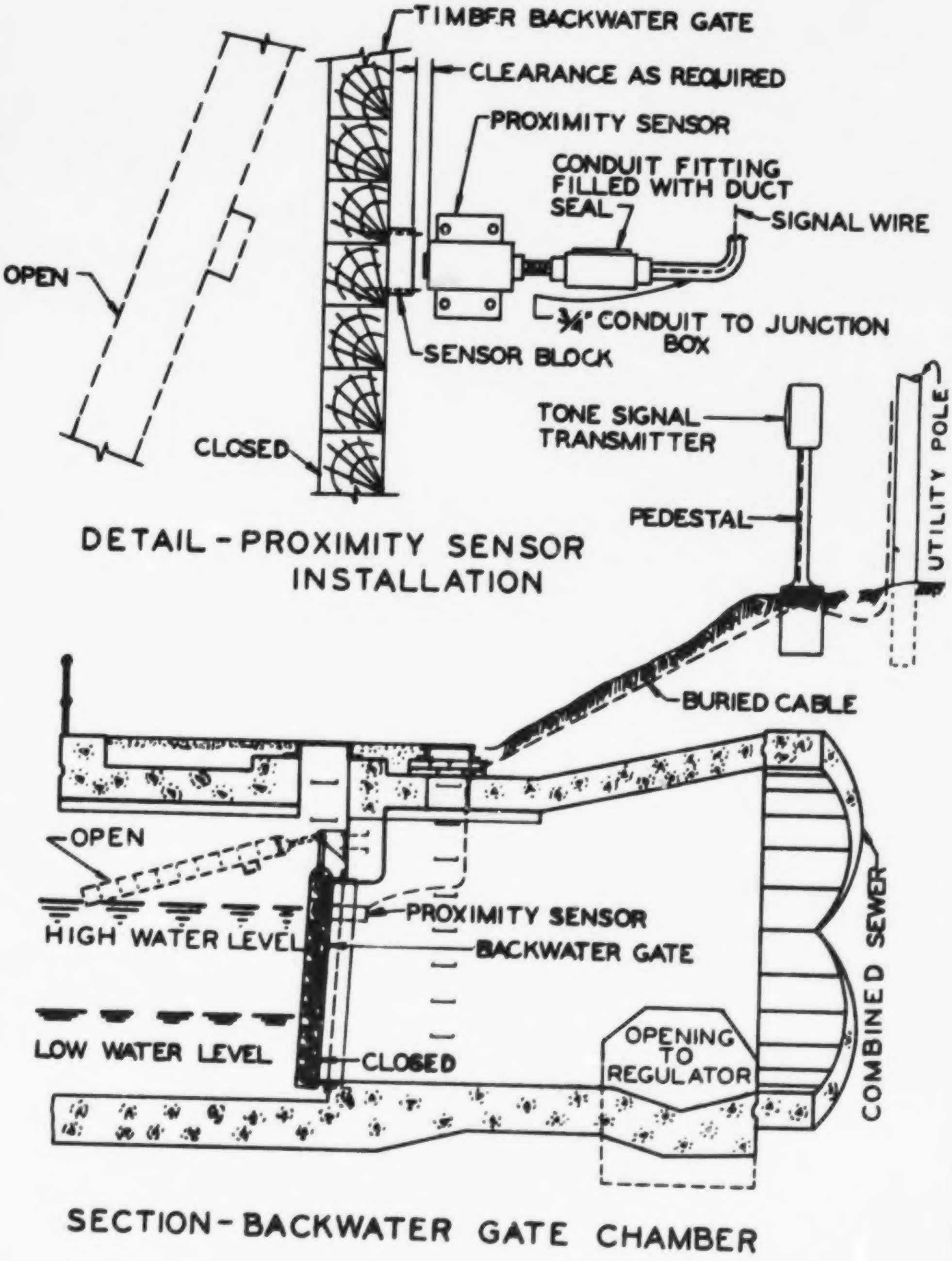


Figure 31-PROXIMITY TYPE STATUS SENSOR

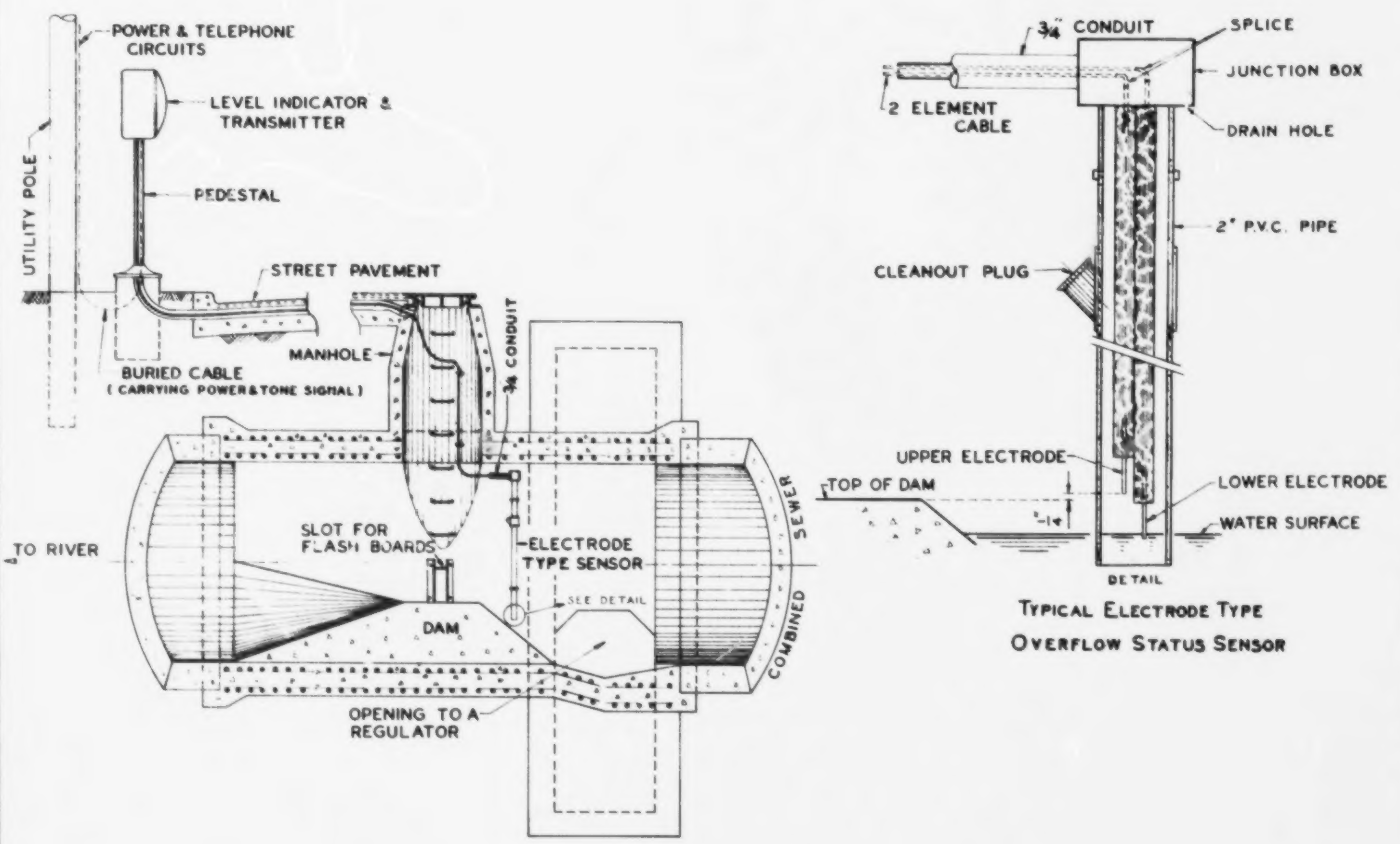


Figure 32- ELECTRODE TYPE STATUS SENSOR

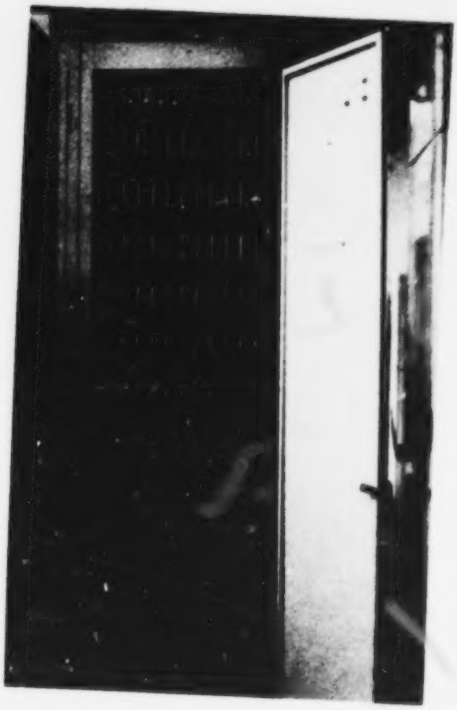


Figure 33 - TONE RECEIVER CABINET

clear space between the active probes. The probes are protected by a 4-inch ID casing with one of the two electrodes located about 1/4-inch above the dam crest. When an overflow occurs, both of the probes are submerged and the circuit is completed. The completed circuit activates a relay which causes the continuous signal transmission to the data acquisition center to stop. During the time for which no signal is received, an overflow is logged.

DIGITAL COMPUTER AND INTERFACE

A total of eight tone transmitter and receiver cabinets were installed. Although each cabinet may contain up to 100 receivers or transmitters, in general the cabinets were not filled to capacity. Wherever possible, the equipment was grouped -- first according to function and second according to geographic location of the monitored points. Sluice gates and regulator controls are in one cabinet, level sensors and status sensors require two cabinets and the remaining five cabinets are used for pump station controls. Figure 33 shows a typical cabinet. Each horizontal bank contains ten receivers and, since up to ten signals with different frequencies may be multiplexed on one leased line, maximum effort was made to have each horizontal bank served by one phone line.

The computer and interface is shown in Figure 34. The present system is designed to accept 475 sensor inputs composed of 250 level sensor signals of both 5-second and 15-second duration; 200 overflow sensor signals; and 25 rain gage signals. Since only 200 sensor signals are presently being received, the system may be expanded with only software modifications.

The system software provides for a number of different functions to be performed by the computer. The software scales the analog-level sensor signals and adds a stored constant to the level sensor reading to account for cell height above invert; tallies pulse counts from rain gages and computes the intensity of rainfall over the preceding 5-minute interval and total rainfall; stores overflow status changes for a given time interval as a check against false signals; increments the real time clock

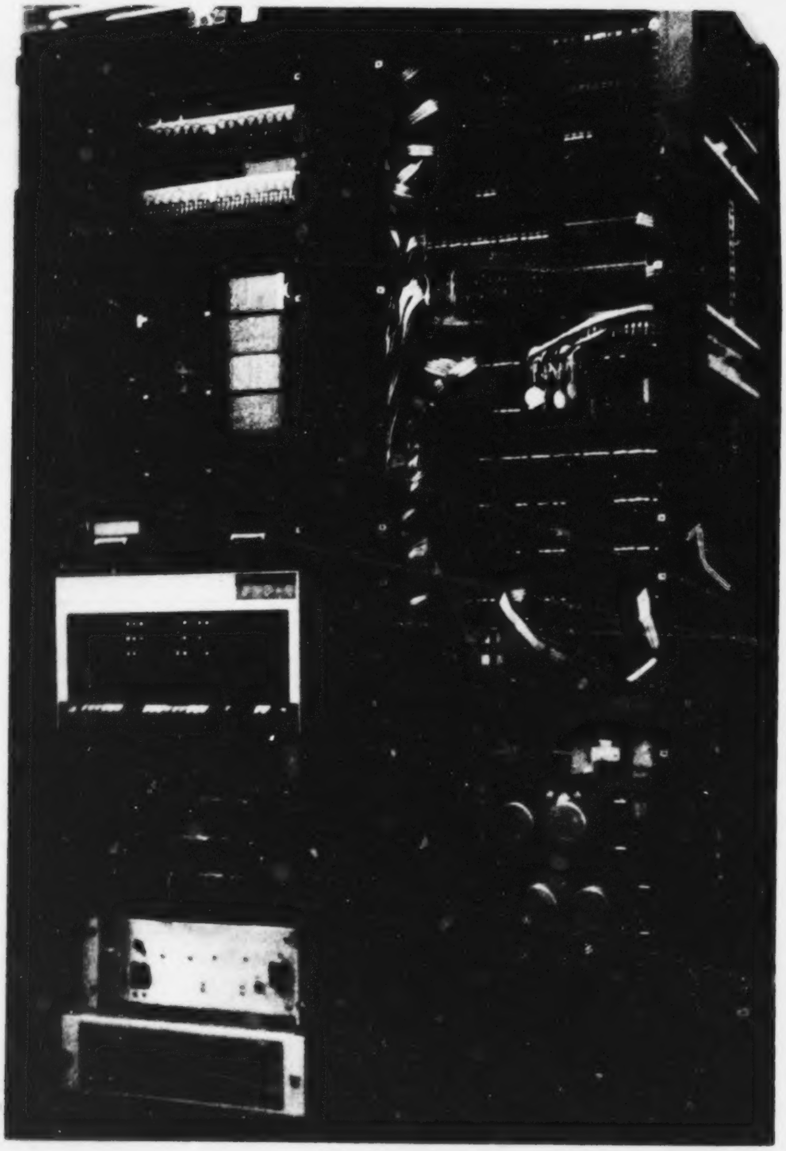


Figure 34 - COMPUTER AND INTERFACE

for the system; generates alarm printouts from programmed set points; and initiates three different printout cycles, an hourly cycle during dry weather flow, a 15-minute cycle when rainfall is detected, and a 5-minute cycle if certain key points rise to alarm levels.

I/O HARDWARE

The operator console, shown on the left of Figure 35, allows the operators to interrupt the executive routine and demand or suppress a data logger printout at any time. This equipment may also be used to monitor any specified sensor point so that observations may be made of the instantaneous changes taking place between data logger printouts. Normally it displays the real time of the computer clock.

The teletypewriter shown on the right side of Figure 36 is used primarily as an output device to display programmed alarms such as high or low wet well elevations, rainfall detection or communications failure from a specific monitor. This unit also serves as a keyboard/paper tape input device. Diagnostic routines and system software are stored on paper tape to facilitate reloading of the computer if necessary.

Output from the data acquisition is logged on three typewriters with 30-inch long platens as shown in Figure 37. Output is in numeric form only with the numeral "0" used to represent gate opening or dam overflow and the numeral "1" to signify that no overflow is occurring at a given point. Level sensor data is printed to the nearest 0.1 foot and rainfall total and intensity to the nearest 0.01 inch and 0.01 inch/hour respectively.

SUPERVISORY CONTROL SYSTEM

The three control panels installed under this project were designed to match the existing water distribution system control panels. The three leftmost panels in Figure 38 are used for control of pump stations, regulators and gates. Figure 39 is a more detailed view of the center panel containing pump station controls and a partial view of the left panel containing gate controls.

The upper section of the control boards contain miniature, 31-day, trend recorders which display wet well elevations independent of the data acquisition system. Mimic busses of the pump stations are on the middle section of the panel. Select-push indicating control switches are used to start and stop pumps and gate operators, as well as to display status and confirmation of changes. Immediately below the sluice gate switches and also to the right of the pump station mimic busses are the alarm indicating lights.

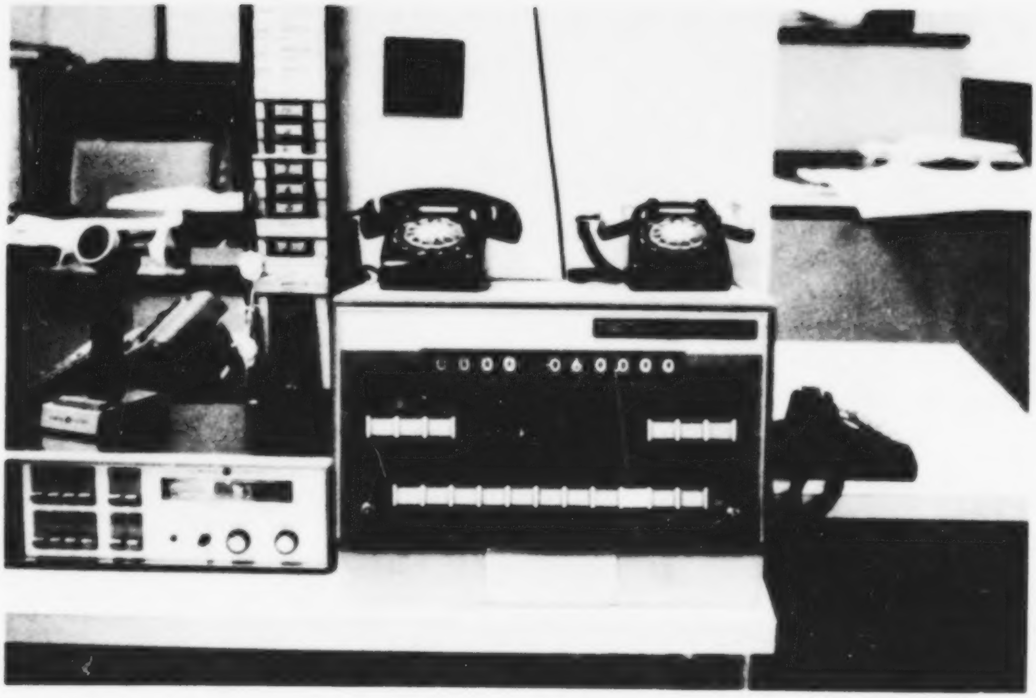


Figure 35 - OPERATOR CONSOLE

Figure 36 - ALARM TELETYPE

Figure 37 - DATA LOGGERS

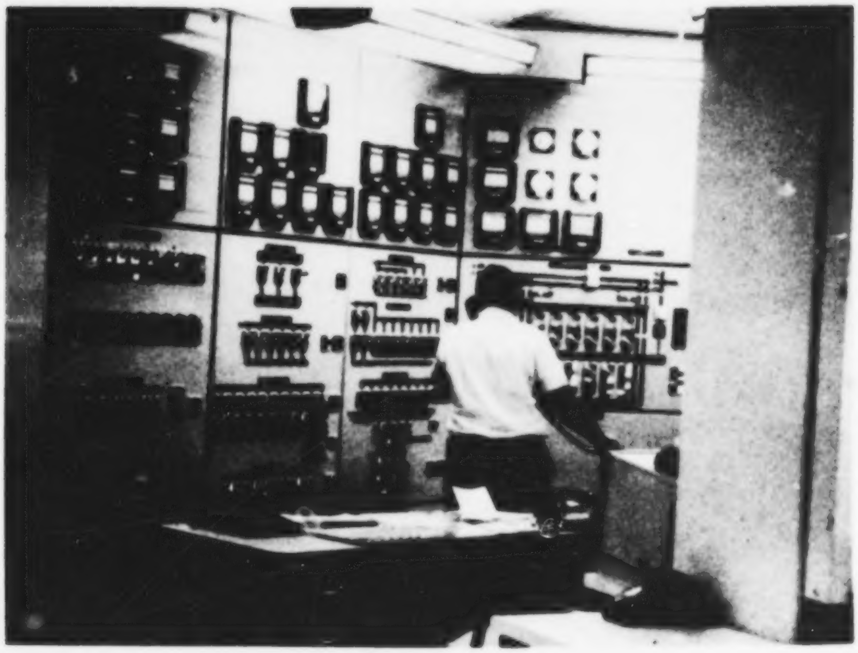


Figure 38 - CONTROL PANELS

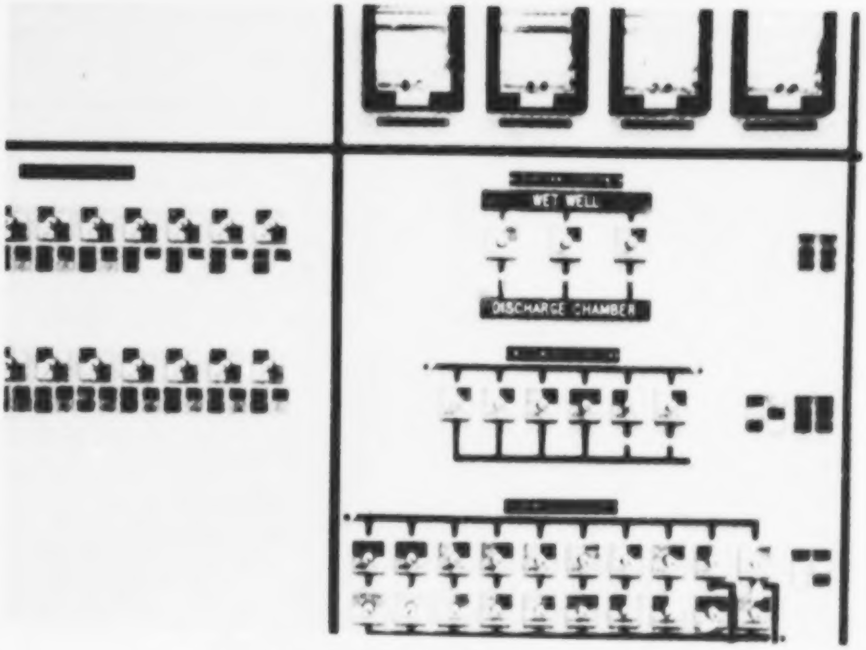


Figure 39 - DETAIL OF CONTROL PANEL

PUMP STATIONS

Seven pump stations containing a total of 39 pumps were converted from local operation to remote operation. The pumps, remotely controlled, range in size from 7 cfs to 500 cfs. Modifications to the existing stations for remote operation required minor electrical work to tie in the necessary transmitters, receivers, relays and scanners.

The eight 500 cfs storm pumps at the Conner Station were not set up for remote control under this project. The storm pumps are over forty years old and have raised impellers that require priming. In October 1971, after the eighteen month project evaluation period had been completed, one of the Conner Station storm pumps was modified for remote operation. The control scheme used proved successful and the remaining seven pumps are now remotely controlled. The pumps at the Wastewater Treatment Plant are monitored at the System Control Center, but are not remotely controlled. Coordination of the operation is done by telephone.

REGULATOR MODIFICATIONS

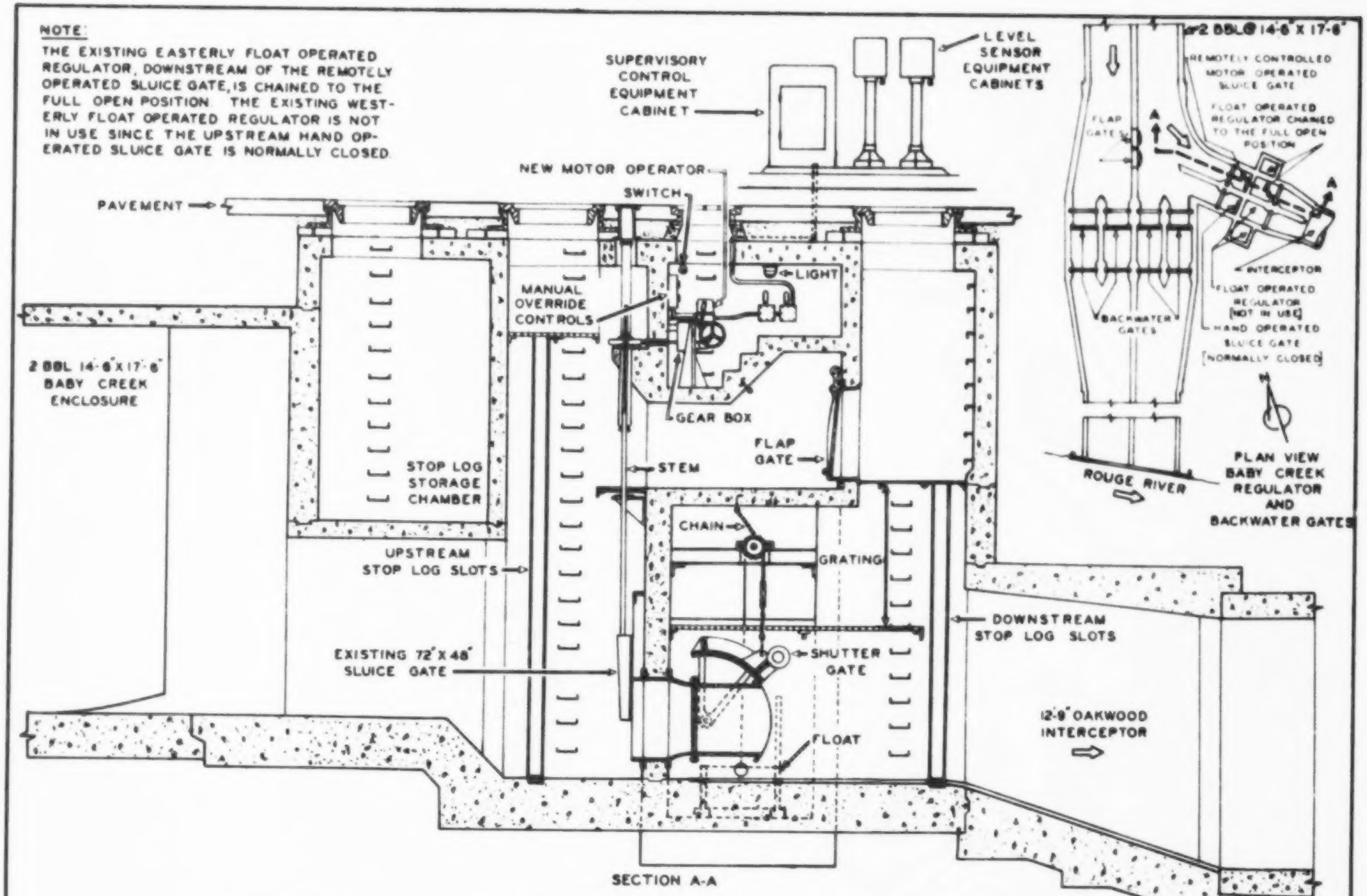
In order to selectively load the interceptor system and to provide for in-system storage, four major regulators at various locations in the system were modified to provide for remote operation.

Baby Creek Regulator

The Baby Creek Regulator, Figure 40, used two float-controlled shutter gates to regulate flow into the Oakwood Interceptor. Hand-operated 72-inches x 48-inches sluice gates were located in the stop log chamber ahead of each shutter gate. These gates were used for diverting flow during maintenance of the shutter gates.

Previous studies had indicated that during dry weather flow, only one of the two regulators was needed. Further, during storm events, the regulators caused the interceptor to surcharge, thus backing up two suburban connections. Secondly, the float-to-gate linkage chains frequently broke because of excessive wear due to surge phenomena in the interceptor.

For these reasons, both shutter gates were chained open; the westerly sluice gate was closed and the easterly sluice gate is remotely controlled. The existing hand-operated sluice gate mechanism required 496 revolutions to fully open the gate from a closed position. The hand wheel was removed and the existing shaft and gearing was coupled to a new gearing system and electric motor drive, as shown in Figure 41. Manual override controls are provided as well as a hand crank in case of power failure.


NOTE:
THE EXISTING EASTERLY FLOAT OPERATED REGULATOR, DOWNSTREAM OF THE REMOTELY OPERATED SLUICE GATE, IS CHAINED TO THE FULL OPEN POSITION. THE EXISTING WESTERLY FLOAT OPERATED REGULATOR IS NOT IN USE SINCE THE UPSTREAM HAND OPERATED SLUICE GATE IS NORMALLY CLOSED.

SUPERVISORY CONTROL EQUIPMENT CABINET
LEVEL SENSOR EQUIPMENT CABINETS
NEW MOTOR OPERATOR
SWITCH
PAVEMENT
LIGHT
MANUAL OVERRIDE CONTROLS
GEAR BOX
FLAP GATE
STEM
2 BBL 14-6"X17-6" BABY CREEK ENCLOSURE
STOP LOG STORAGE CHAMBER
CHAIN
GRATING
UPSTREAM STOP LOG SLOTS
DOWNSTREAM STOP LOG SLOTS
EXISTING 72"X48" SLUICE GATE
SHUTTER GATE
FLOAT
12'-9" OAKWOOD INTERCEPTOR
SECTION A-A
2 BBL @ 14'-6" X 17'-6"
REMOTELY CONTROLLED MOTOR OPERATED SLUICE GATE
FLOAT OPERATED REGULATOR CHAINED TO THE FULL OPEN POSITION
FLAP GATES
A
A
INTERCEPTOR
FLOAT OPERATED REGULATOR [NOT IN USE]
HAND OPERATED SLUICE GATE [NORMALLY CLOSED]
BACKWATER GATES
N
ROUGE RIVER
PLAN VIEW BABY CREEK REGULATOR AND BACKWATER GATES

Figure 40-MODIFICATIONS AT THE BABY CREEK REGULATOR

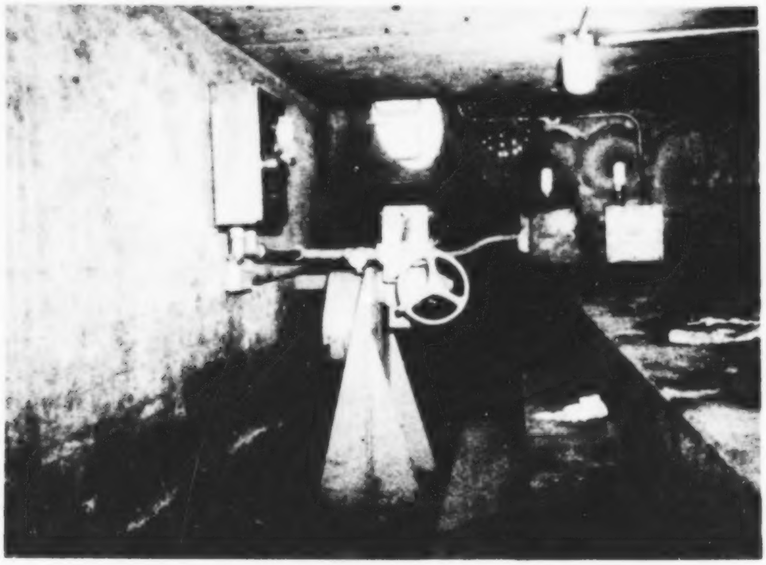


Figure 41 - MOTOR OPERATOR AT BABY CREEK

Hubbell-Southfield Regulator

Modifications to the Hubbell-Southfield regulator, Figure 42, were similar to those made at Baby Creek. In this case, however, sluice gates had to be fabricated since there were no existing gates. The two Brown and Brown float-controlled regulators were chained to the full open position. As in all the installations, on-site manual override to the remote control equipment is provided, as well as a hand crank.

The motor operator in Figure 43 is located above a grating in the stop log chamber and supported by two wide flange beams. Because this installation was not in a separate chamber, as in the case of the Baby Creek Regulator, and would be subjected to gases and moisture, the gate stem was greased and then enclosed in a plexiglass tube.

Figure 44 shows the control equipment cabinets. The two larger cabinets contain the control equipment for each gate and the smaller cabinet contains level sensor equipment as discussed previously. Figure 45 is a view of the inside of one of the control cabinets. The tone equipment necessary for remote operation is mounted in an eleven-module rotating rack. Tone modules are plugged into this rack and may be removed easily if maintenance is required. All other remote control installations are similarily designed.

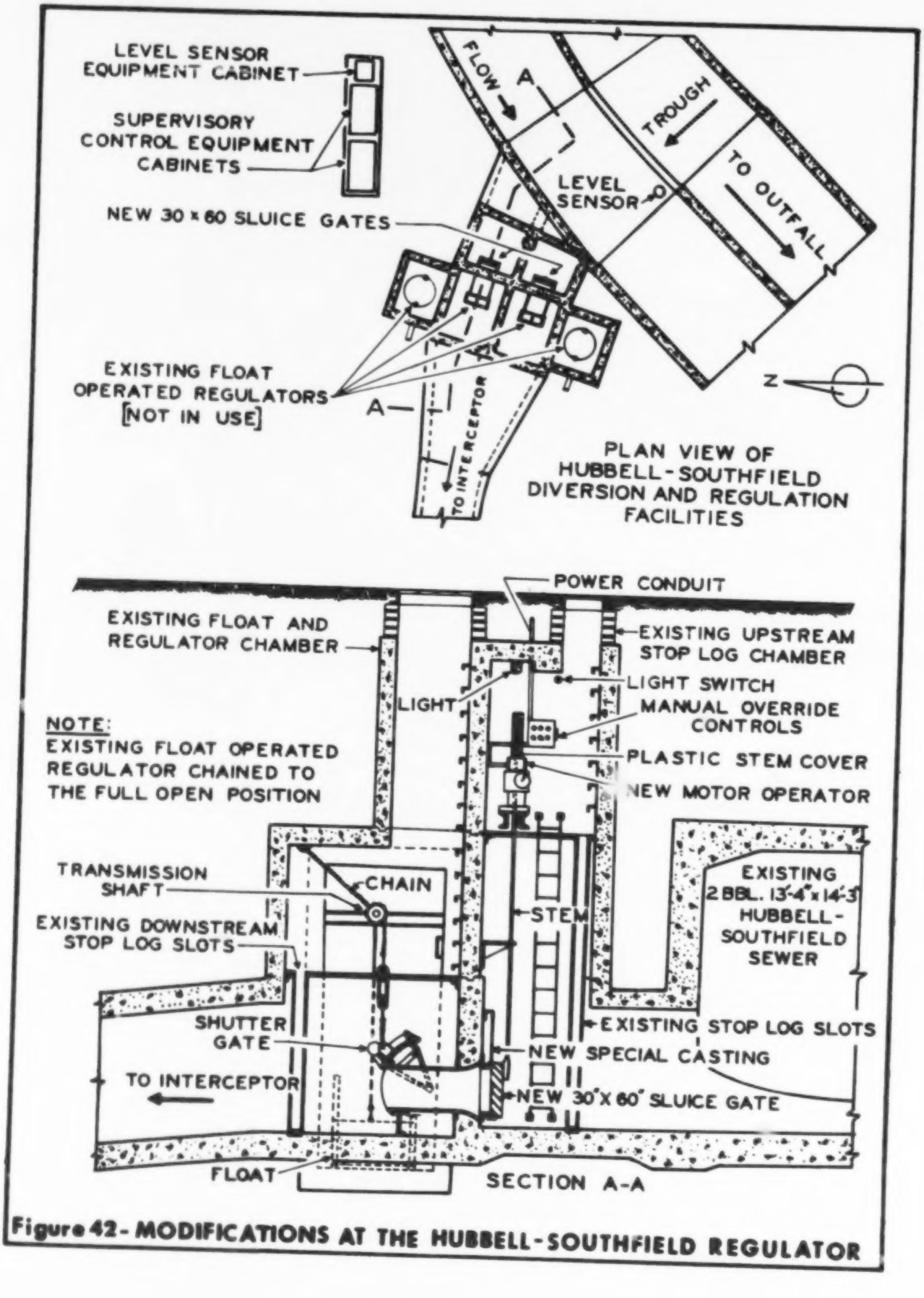

LEVEL SENSOR EQUIPMENT CABINET
SUPERVISORY CONTROL EQUIPMENT CABINETS
NEW 30 x 60 SLUICE GATES
FLOW
A
TROUGH
LEVEL SENSOR
TO OUTFALL
EXISTING FLOAT OPERATED REGULATORS [NOT IN USE]
A
TO INTERCEPTOR
Z
PLAN VIEW OF HUBBELL-SOUTHFIELD DIVERSION AND REGULATION FACILITIES
POWER CONDUIT
EXISTING FLOAT AND REGULATOR CHAMBER
EXISTING UPSTREAM STOP LOG CHAMBER
LIGHT SWITCH
LIGHT
MANUAL OVERRIDE CONTROLS
NOTE:
EXISTING FLOAT OPERATED REGULATOR CHAINED TO THE FULL OPEN POSITION
PLASTIC STEM COVER
NEW MOTOR OPERATOR
TRANSMISSION SHAFT
CHAIN
STEM
EXISTING 2 BBL. 13'-4" x 14'-3" HUBBELL-SOUTHFIELD SEWER
EXISTING DOWNSTREAM STOP LOG SLOTS
SHUTTER GATE
EXISTING STOP LOG SLOTS
NEW SPECIAL CASTING
TO INTERCEPTOR
NEW 30" X 60" SLUICE GATE
FLOAT
SECTION A-A

Figure 42 - MODIFICATIONS AT THE HUBBELL-SOUTHFIELD REGULATOR

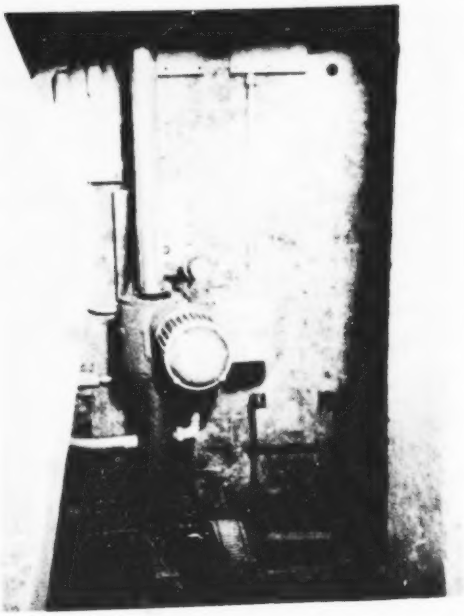


Figure 43 - MOTOR OPERATOR AT HUBBELL-SOUTHFIELD

Figure 44 - CONTROL EQUIPMENT CABINETS

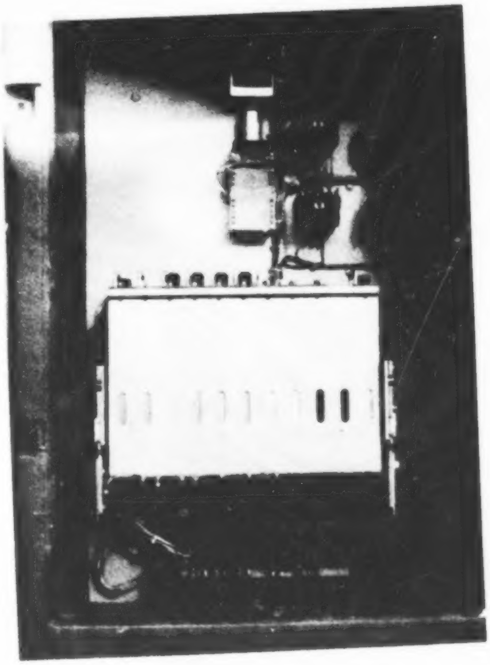


Figure 45 - DETAIL OF CONTROL EQUIPMENT

Warren-Pierson Regulator

Prior to construction of the southerly section of the Northwest Interceptor, a pump station was located at Warren and Pierson. With the construction of the deep interceptor in 1958, the pumps were removed and a float-controlled, hydraulic cylinder-operated gate was installed. The section of the Northwest Interceptor above the Warren-Pierson Regulator contains no regulators and flow is diverted into the combined sewer by dams. With the increased urbanization of the upper Rouge River Basin, the river crested at higher elevations, topped the dams and flooded the interceptor. The backwater gates are now being installed at outfalls north of the Warren-Pierson Regulator to alleviate this problem.

To implement the concept of "Selective overflowing", this regulator was modified for remote control. The existing hydraulic cylinder was reconditioned and remote control equipment installed. Since failure of the hydraulic cylinder at this location would cause raw sewage to overflow into the Rouge River and leaky seals on the cylinder would allow the gate to drift downward during dry weather flow, with the resultant possibility of an overflow, a concrete counterweight was cast and connected with stainless steel rope as shown in Figure 46. This is designed to equalize the load on the hydraulic cylinder.

Conner Forebay Regulator

In 1962, the original toggle type regulators were replaced with float-controlled, hydraulic cylinder-operated gates. Since these were relatively new, it was decided to remotely control the cylinders rather than the electric sluice gate operators installed in 1927. Figure 47 shows the modifications made to the regulator. The regulator controlled by the 48-inch knife gate is of sufficient capacity to allow dry weather flow into the interceptor. Thus, by remotely controlling all three gates, a backup system is provided if a gate fails to operate.

CONNER FLUSHING GATES

A 10'-0" x 7'-0" roller gate was installed in each of the three barrels of the Conner Gravity Sewer at the transition from a 12'-0" x 16'-6" two-barrel box to a 15'-9" x 17'-6" three-barrel box. This transition section is located approximately 8500 feet upstream of the Conner Forebay Regulator. The gates are being used to test the concept of using dry weather flow to flush combined sewers.

As shown in Figure 48, a chamber was constructed on the top of the sewer. The chamber size (and thus the gate height) was limited by the fact that the top of the sewer was about 11.5 feet below the street surface. Each gate is raised and lowered by means of a cable drum hoist with a Limitorque electric operator. Since debris and sludge deposits were found in the sewer, it was believed that the gates might jam due to uneven seating.

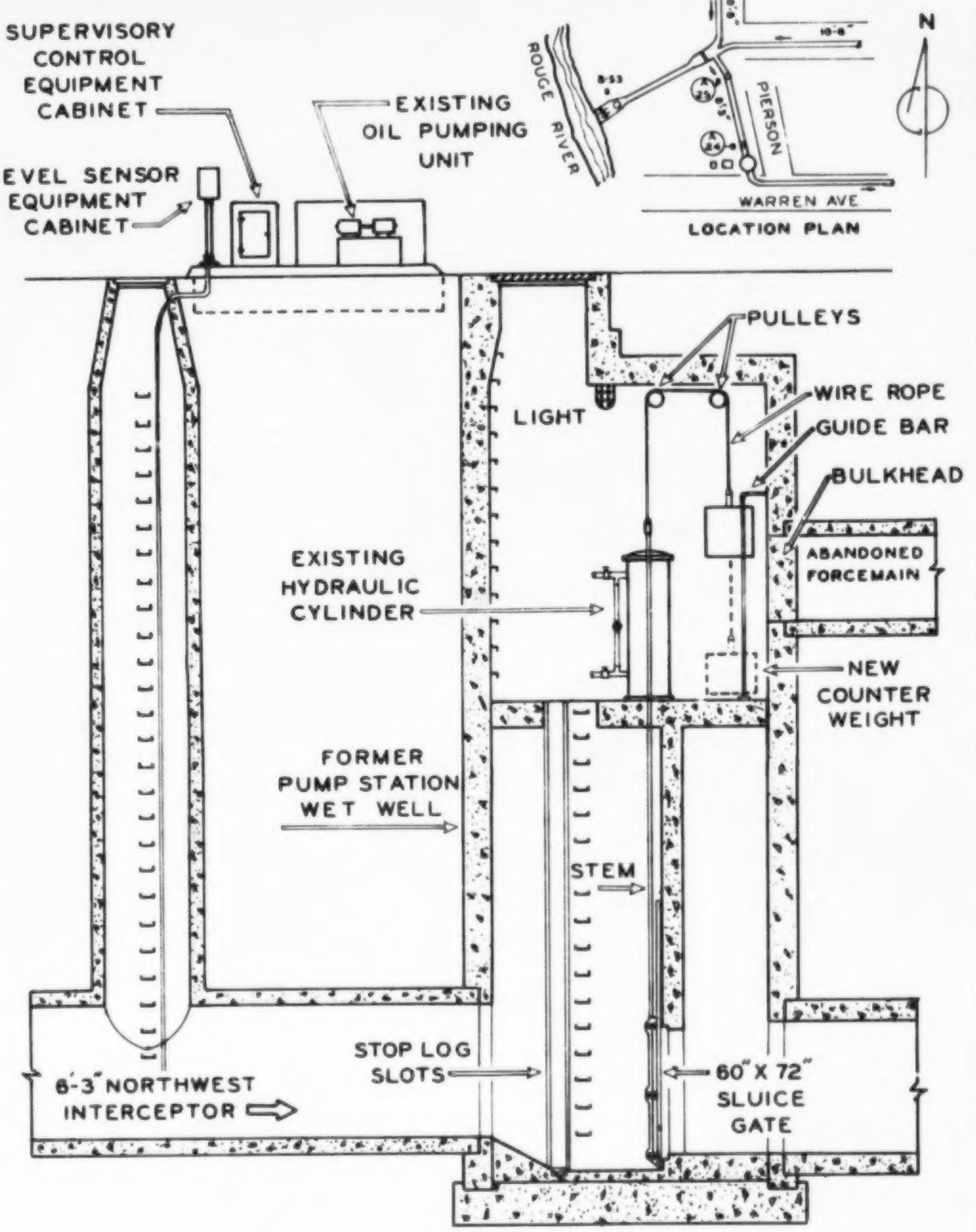

SUPERVISORY CONTROL EQUIPMENT CABINET
EXISTING OIL PUMPING UNIT
LEVEL SENSOR EQUIPMENT CABINET
ROUGE RIVER
10'-6"
PIERSON
WARREN AVE
LOCATION PLAN
N
PULLEYS
LIGHT
WIRE ROPE
GUIDE BAR
BULKHEAD
ABANDONED FORCEMAIN
EXISTING HYDRAULIC CYLINDER
NEW COUNTER WEIGHT
FORMER PUMP STATION WET WELL
STEM
STOP LOG SLOTS
60" X 72" SLUICE GATE
6'-3" NORTHWEST INTERCEPTOR

Figure 46 - MODIFICATIONS AT THE WARREN - PIERSON REGULATOR

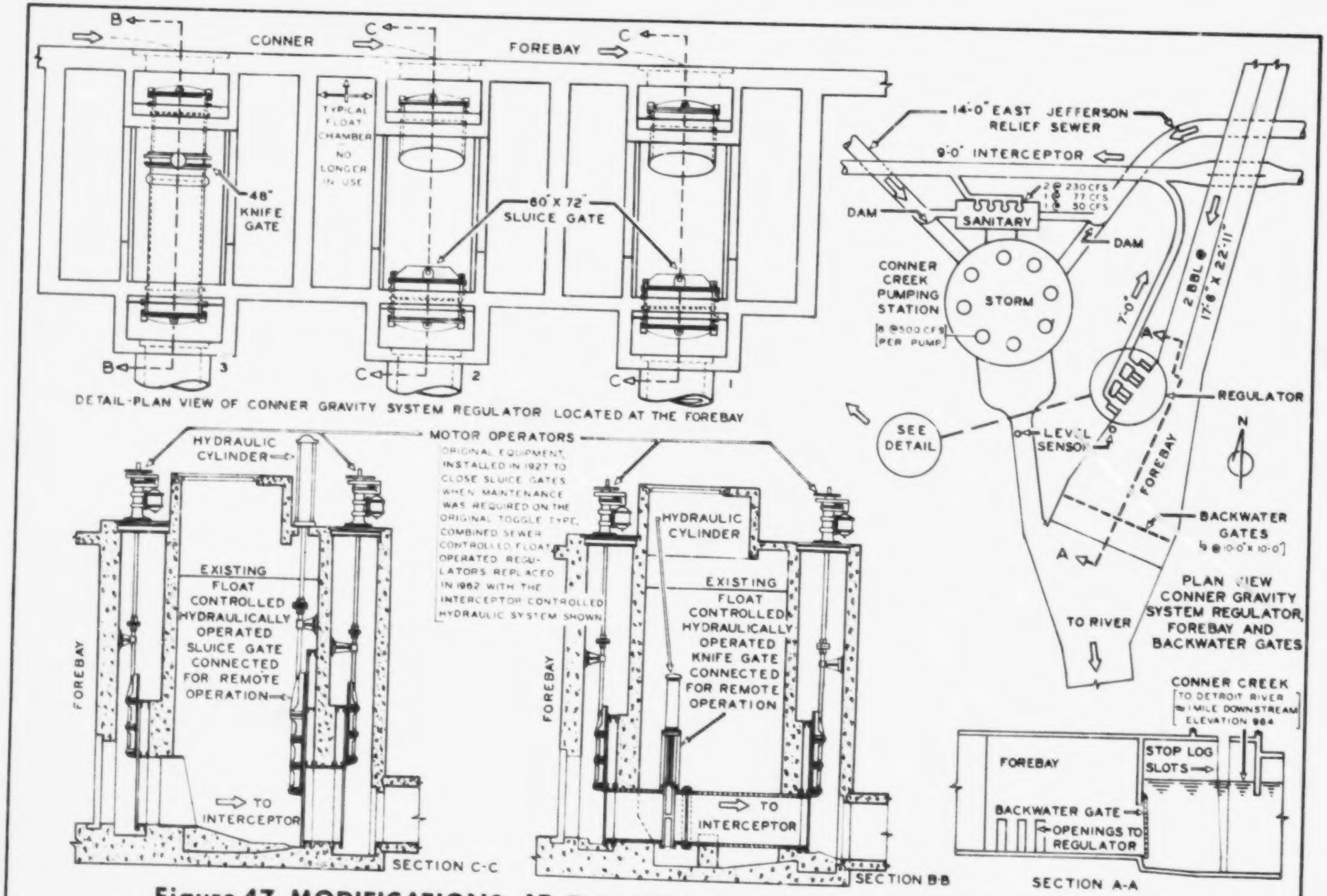

CONNER
FOREBAY
B
C
C
48" KNIFE GATE
TYPICAL FLOAT CHAMBER NO LONGER IN USE
60" X 72" SLUICE GATE
1
2
3
DETAIL-PLAN VIEW OF CONNER GRAVITY SYSTEM REGULATOR LOCATED AT THE FOREBAY
MOTOR OPERATORS
ORIGINAL EQUIPMENT, INSTALLED IN 1927 TO CLOSE SLUICE GATES WHEN MAINTENANCE WAS REQUIRED ON THE ORIGINAL TOGGLE TYPE, COMBINED SEWER CONTROLLED FLOAT OPERATED REGULATORS REPLACED IN 1962 WITH THE INTERCEPTOR CONTROLLED HYDRAULIC SYSTEM SHOWN
HYDRAULIC CYLINDER
EXISTING FLOAT CONTROLLED HYDRAULICALLY OPERATED SLUICE GATE CONNECTED FOR REMOTE OPERATION
FOREBAY
TO INTERCEPTOR
SECTION C-C
HYDRAULIC CYLINDER
EXISTING FLOAT CONTROLLED HYDRAULICALLY OPERATED KNIFE GATE CONNECTED FOR REMOTE OPERATION
FOREBAY
TO INTERCEPTOR
SECTION B-B
14'-0" EAST JEFFERSON RELIEF SEWER
9'-0" INTERCEPTOR
2 @ 230 CFS
1 @ 77 CFS
1 @ 50 CFS
SANITARY
DAM
DAM
CONNER CREEK PUMPING STATION
[8 @ 500 CFS PER PUMP]
STORM
7'-0"
2 BBL @ 17'-6" X 22'-11"
A
REGULATOR
SEE DETAIL
LEVEL SENSOR
FOREBAY
N
BACKWATER GATES
[4 @ 10'-0" X 10'-0"]
A
TO RIVER
PLAN VIEW CONNER GRAVITY SYSTEM REGULATOR, FOREBAY AND BACKWATER GATES
CONNER CREEK
[TO DETROIT RIVER ≈ 1 MILE DOWNSTREAM ELEVATION 984]
FOREBAY
STOP LOG SLOTS
BACKWATER GATE
OPENINGS TO REGULATOR
SECTION A-A

Figure 47-MODIFICATIONS AT THE CONNER GRAVITY SYSTEM REGULATOR

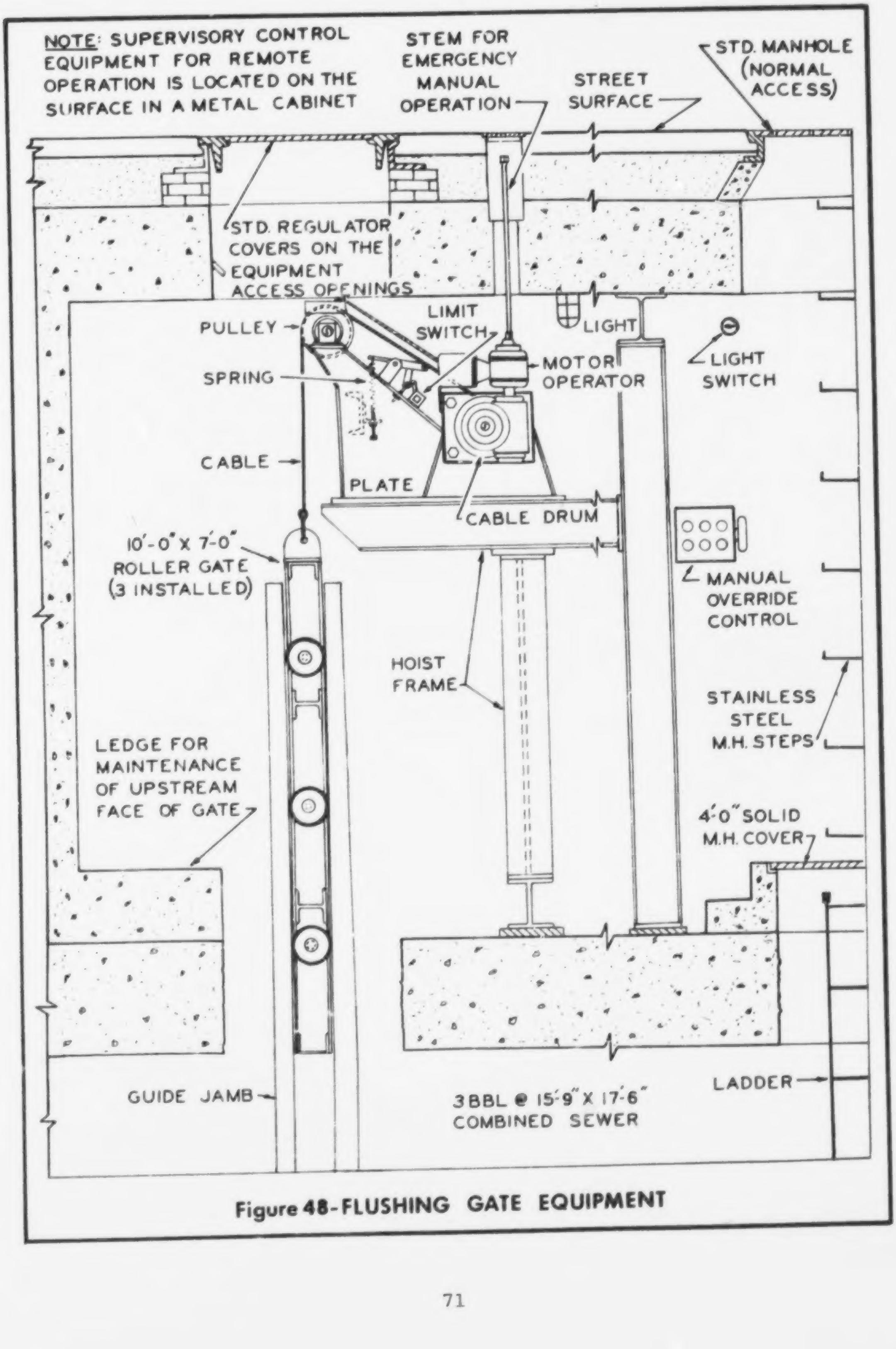

NOTE: SUPERVISORY CONTROL EQUIPMENT FOR REMOTE OPERATION IS LOCATED ON THE SURFACE IN A METAL CABINET
STEM FOR EMERGENCY MANUAL OPERATION
STREET SURFACE
STD. MANHOLE (NORMAL ACCESS)
STD. REGULATOR COVERS ON THE EQUIPMENT ACCESS OPENINGS
LIMIT SWITCH
PULLEY
LIGHT
SPRING
MOTOR OPERATOR
LIGHT SWITCH
CABLE
PLATE
CABLE DRUM
10'-0" X 7'-0" ROLLER GATE (3 INSTALLED)
MANUAL OVERRIDE CONTROL
HOIST FRAME
STAINLESS STEEL M.H. STEPS
LEDGE FOR MAINTENANCE OF UPSTREAM FACE OF GATE
4'-0" SOLID M.H. COVER
GUIDE JAMB
3 BBL @ 15'-9" X 17'-6" COMBINED SEWER
LADDER

Figure 48-FLUSHING GATE EQUIPMENT

For this reason, the hoist was designed with the cables on each end of the gate. A mechanical linkage was installed so that the Limitorque would automatically reverse gate travel if one of the two cables slackened prior to the preset gate travel limits.

Figure 49 shows the hoist and Limitorque operator with the roller gate in the open position. Figure 50 shows the manual override controls as well as the hoist mechanism. Notice the hole in the roof, directly above the operator. A stem was extended from the operator to the street surface to provide for manual opening of the gates. The stem is compatible with existing water system gate valve stems which may be manually operated or operated utilizing power take-off equipment from a truck. If the remote control equipment should become inoperable when the gates are in a down position, it is possible for the flow to top the gates without causing upstream flooding. Thus, an additional safety factor is provided if maintenance crews are delayed in opening the gates manually.

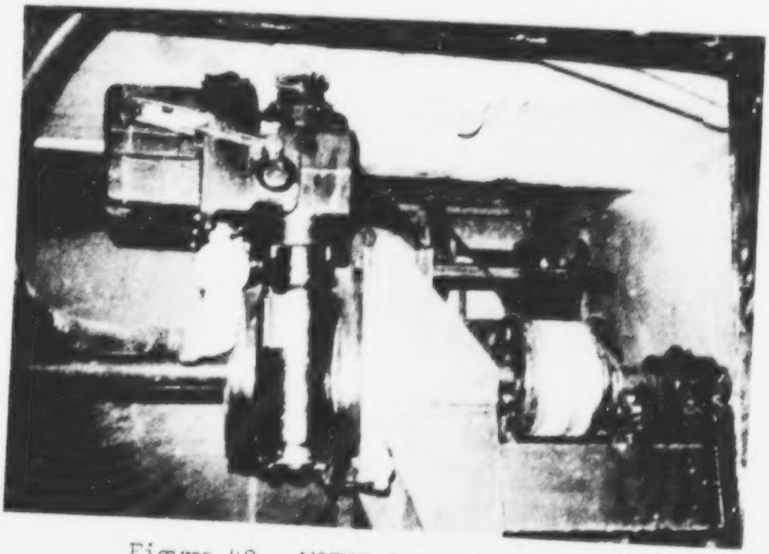


Figure 49 - MOTOR OPERATOR AT CONNER

Figure 50 - OVERRIDE CONTROLS

SECTION VII

SAMPLING

Efforts to optimize in-system storage, first flush interception and selective overflowing would have little value if the pollutional concentration of each sewer were unknown. Although studies related to rainfall analysis, runoff characteristics, flow in sewers and location and duration of combined sewer overflows are valuable, they would not be complete without sampling (21). For this reason, a combined sewer sampling program was initiated. Both a manual grab sample program and an automatic sampling program were set up.

GRAB SAMPLING PROGRAM

A two-quart grab sample was taken hourly each weekday between 9:00 a.m. and 3:00 p.m. at a point on each combined sewer outfall immediately upstream of the regulator or diversion chamber. Due to the diversity of outfall locations, approximately 6 months were required to obtain samples from all of the outfalls. Two additional sampling circuits were completed during the project period. Between 25 and 35 samples were taken at every outfall for each circuit. The majority of the samples were collected during dry weather flow periods.

Sewer samples were refrigerated and delivered to the Wastewater Plant daily for analysis of suspended solids, biochemical oxygen demand, total phosphate, phenols, oil and grease. Analysis of Rouge River samples included suspended solids, biochemical oxygen demand, and total coliforms. The averages of the analysis results may be found in Tables 1 through 3 of Appendix A. Figures 51 through 59 are a graphical representation of the concentrations of biochemical oxygen demand, oil and grease, and suspended solids for each of the sampling points for each circuit.

The graphical figures and the accompanying tables give some indication as to the variation of pollutional concentrations in the sewer system. The distribution of industrial, business and residential districts within the city is also reflected by these figures. The east side and northwest side of the city are mostly residential. As can be seen for these areas, the pollutional concentrations are fairly uniform and reflect residential type wastes. Slaughterhouse, meatpacking, market areas and breweries are drained by the 21st Street, Orleans, St. Aubin, Dubois and Chene Sewers. The higher pollutional concentrations in these sewers is evident. Heavy industry is located in the southwest section of the city. This includes refineries, metal works, cement plants, etc. Both suspended solids and oil and greases are high in the sewers servicing this area. As could be expected, phenols are also relatively high (23).

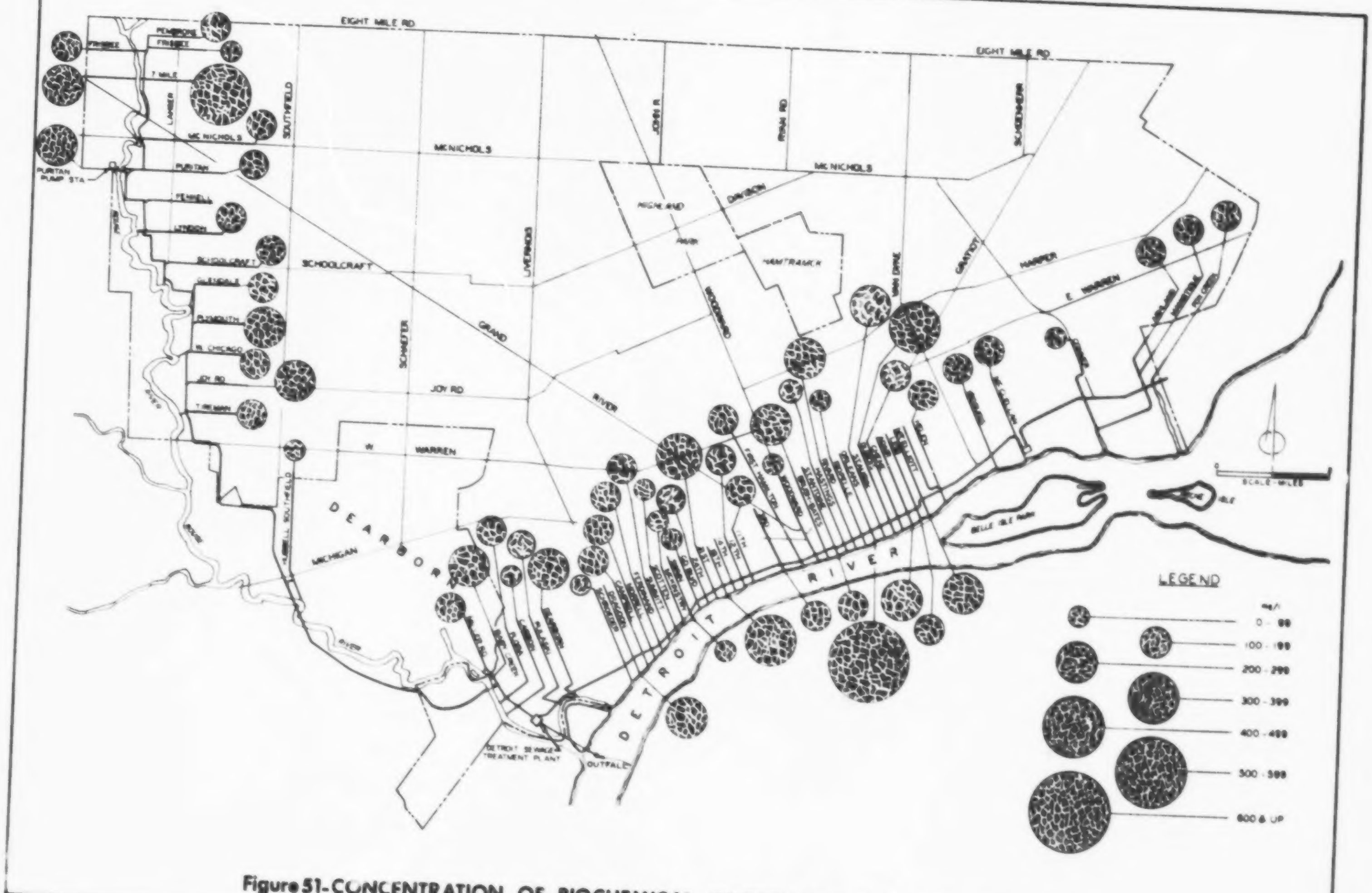


Figure 51-CONCENTRATION OF BIOCHEMICAL OXYGEN DEMAND, JUN 68-DEC 68

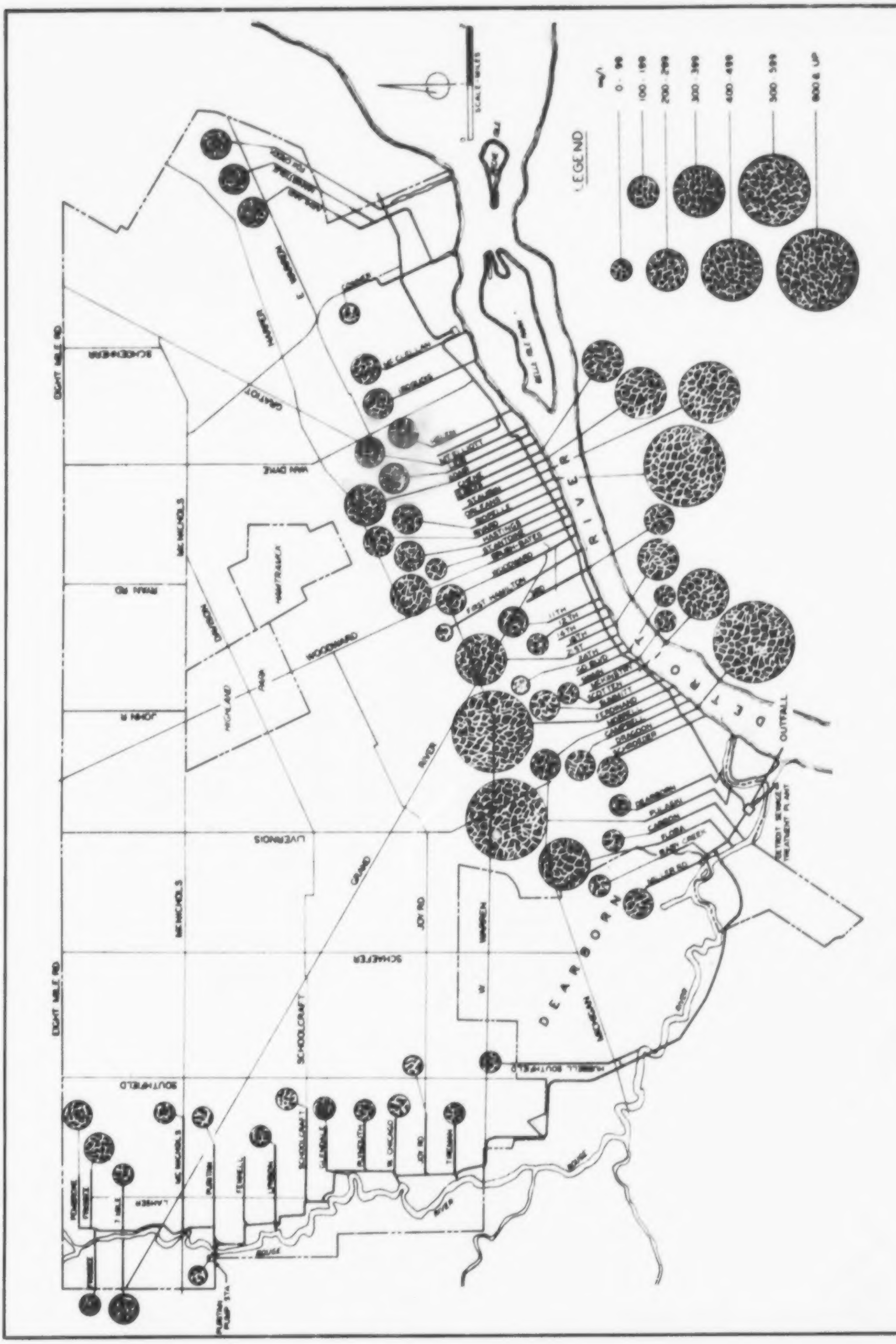


Figure 52-CONCENTRATION OF BIOCHEMICAL OXYGEN DEMAND, JAN 69-JUL 69

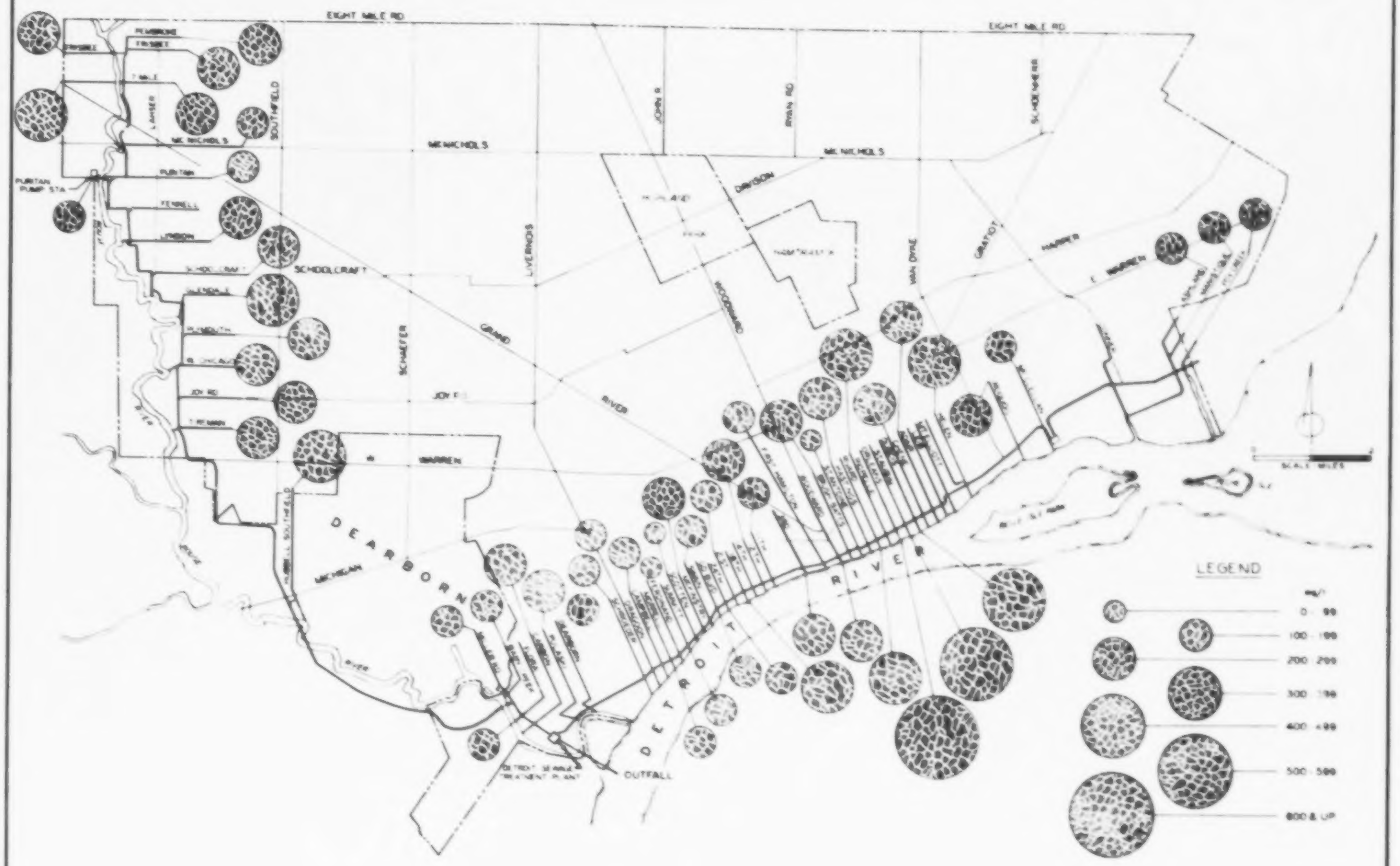


Figure 53-CONCENTRATION OF BIOCHEMICAL OXYGEN DEMAND, AUG 69 - MAR 70

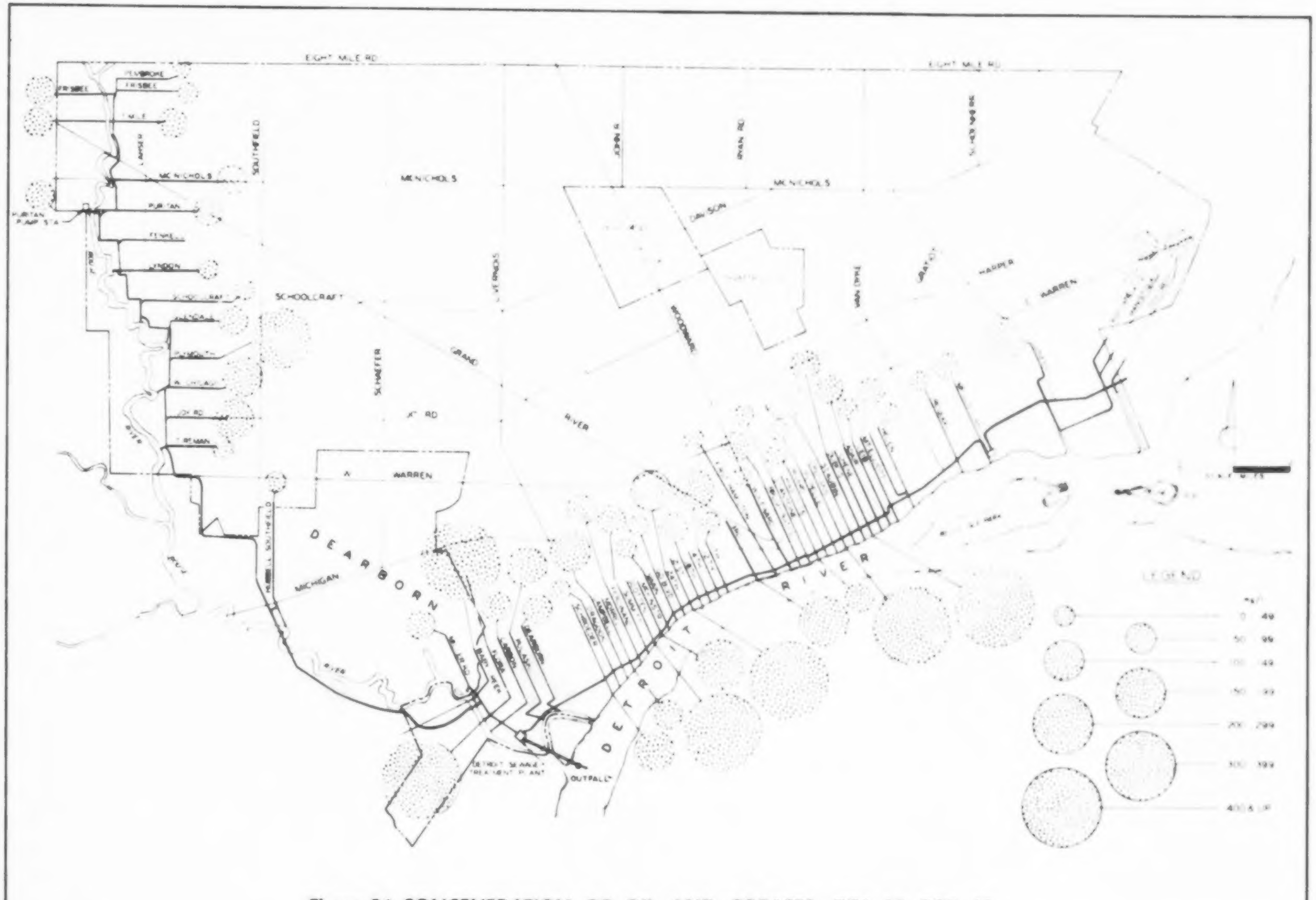


Figure 54-CONCENTRATION OF OIL AND GREASES, JUN 68-DEC 68

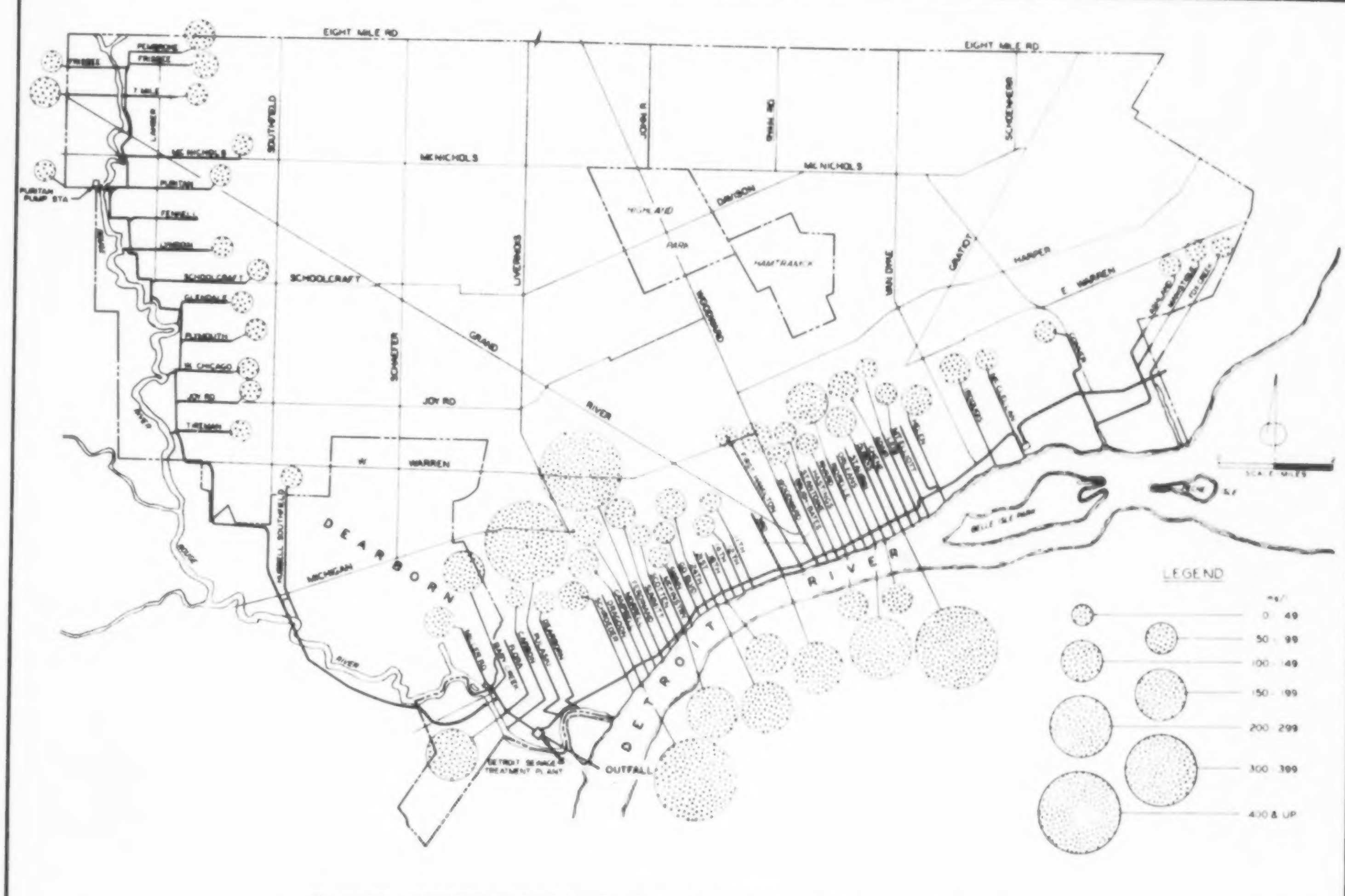


Figure 55- CONCENTRATION OF OIL AND GREASES, JAN 69-JUL 69

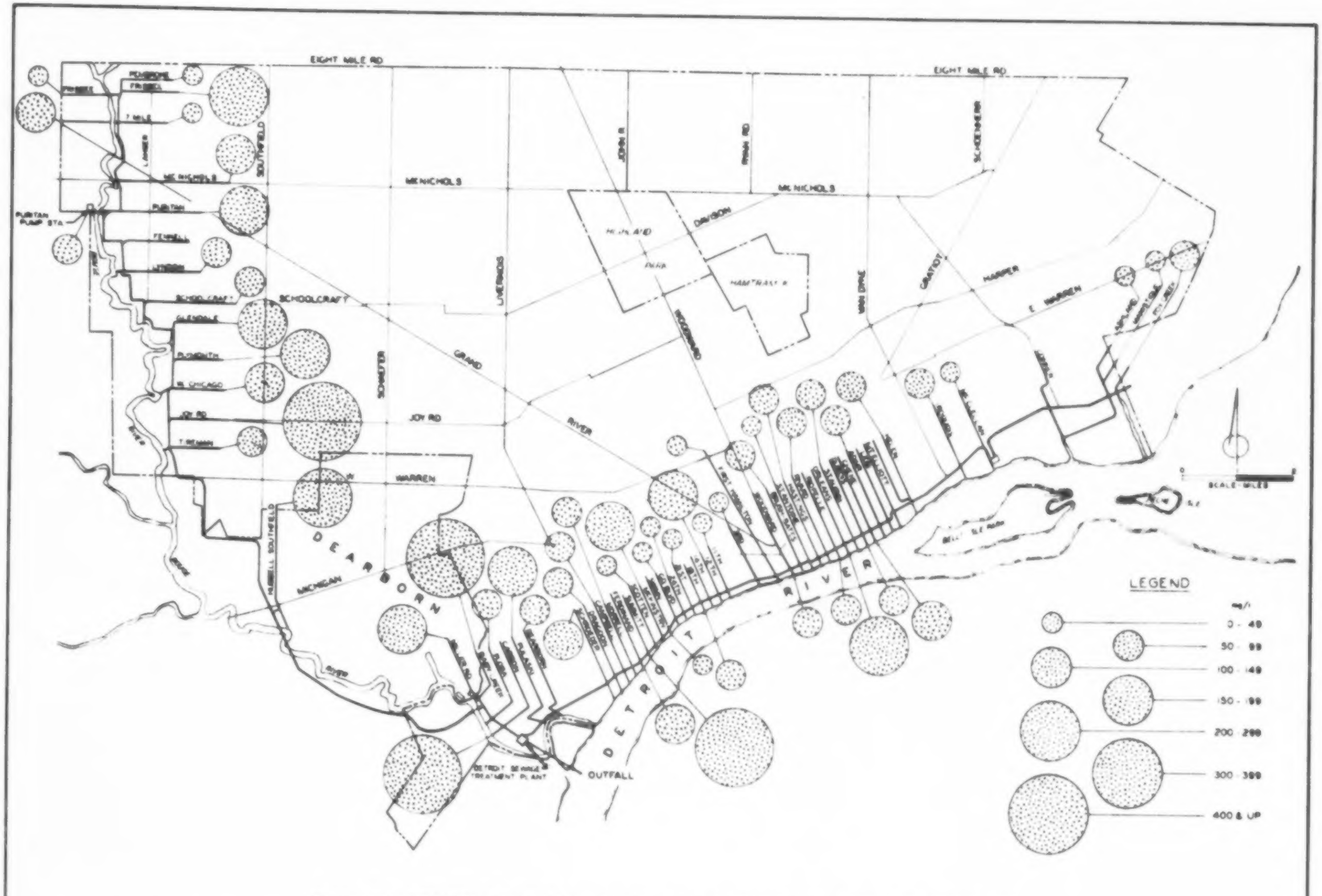


Figure 56-CONCENTRATION OF OIL AND GREASES, AUG 69-MAR 70

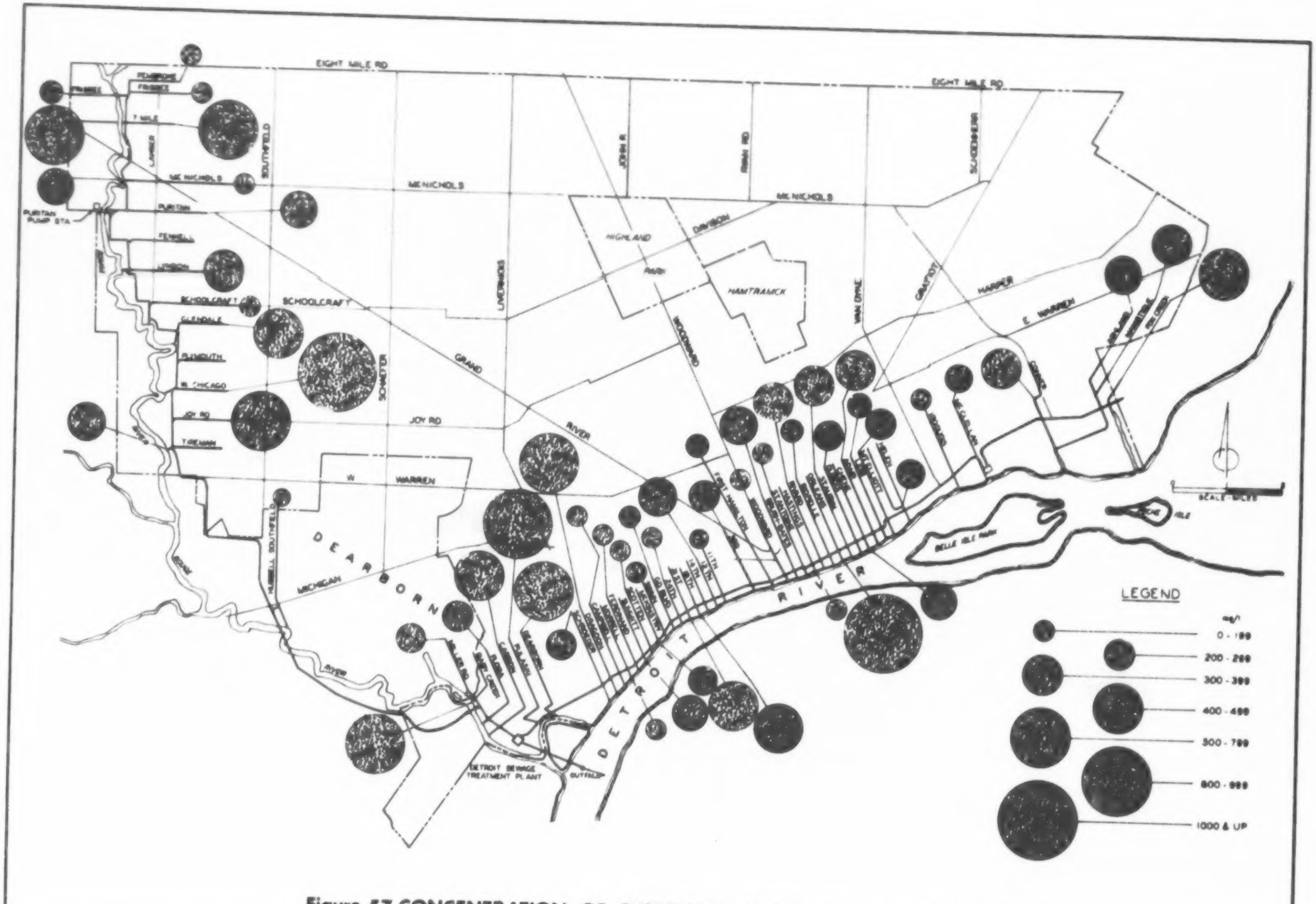


Figure 57-CONCENTRATION OF SUSPENDED SOLIDS, JUN 68-DEC 68

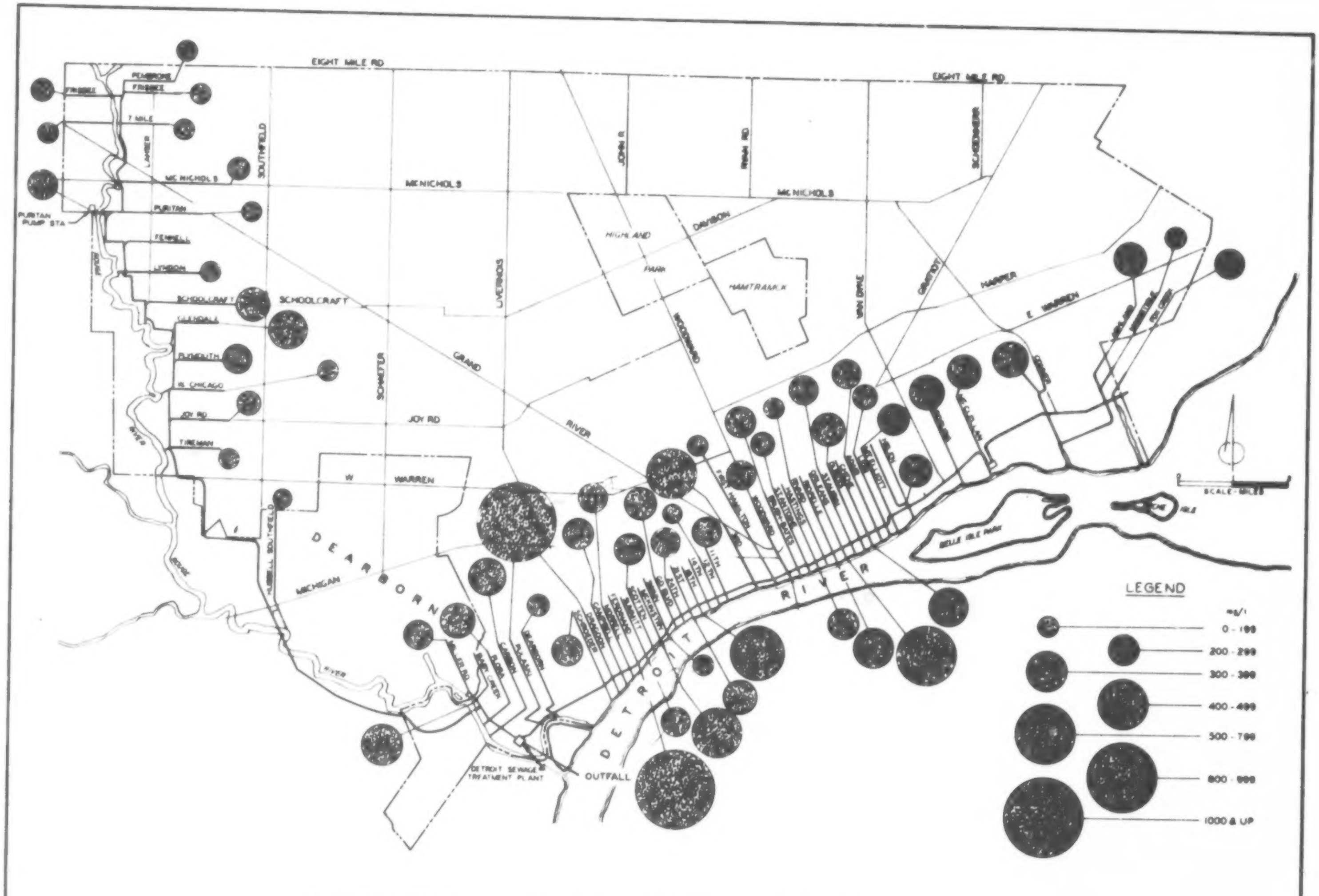


Figure 58-CONCENTRATION OF SUSPENDED SOLIDS, JAN 69 - JUL 69

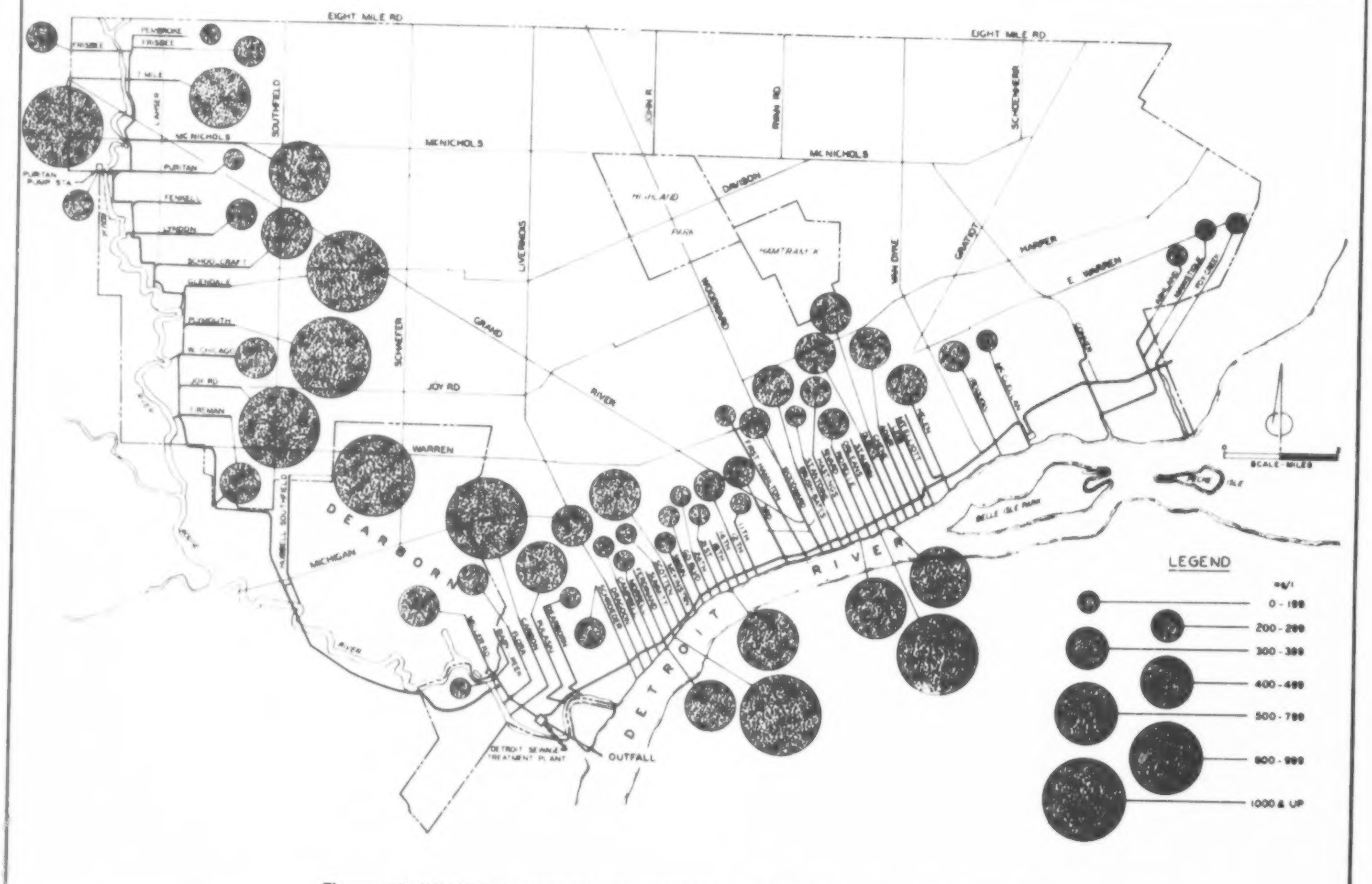


Figure 59-CONCENTRATION OF SUSPENDED SOLIDS, AUG 69-MAR 70

Approximately 200 grab samples were taken at each of twelve sample points along the Rouge River and tributary branches (24). The results of the analysis are summarized in Figure 60. It was hoped that this sampling program would be of aid in determining which areas of the Rouge River were most heavily polluted. With this knowledge, steps could then be taken to alleviate part of the problem by modifying existing dams or regulators. However, as can be seen in the averages shown, there is no area in which there appears to be a significant increase in pollutants.

Following storm events, the concentrations of the pollutants measured did increase significantly. However, as in the case of the average values, there were no trends toward specific areas being more polluted than others.

AUTOMATIC SAMPLING PROGRAM

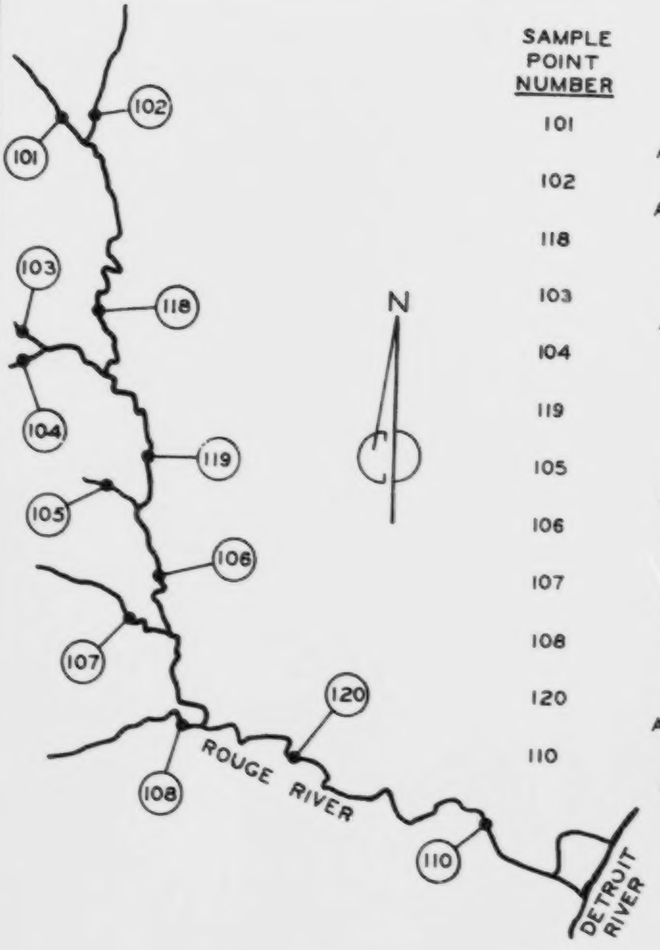
Those familiar with sampling of combined sewer overflows have probably found that nature rarely cooperates with sampling crews. Combined sewer overflows can be expected to occur any time the sampling crew is not at the site. This prompted an automatic sampling program to be set up in conjunction with the grab sample program.

The desired mode of operation of the sampler was to locate the sample line downstream of dams or regulators so that only actual combined sewer overflows would be sampled. Because samples would be taken only during actual overflows, a vacuum-type suction pump was selected. This type of pump can run continuously without damage to itself even if there is no flow to be sampled. The Megator sampler selected for the project takes a continuous sample and cycles every 1/2 hour to fill a new sample bottle. The sampler has 48 - 20-ounce sample bottles.

Because of the cyclic nature of the sampler and the type of pump selected, not only could combined sewer overflow samples be obtained but also the time of the start of the overflow and the duration could be established by noting which sample bottles were filled.

Since this was DMWD's first experience with an automatic sampler for combined sewer overflows, it was decided to locate the sampler on a combined sewer upstream of the overflow for test purposes. The West End Relief Sewer was chosen since it carried a small amount of dry weather flow (approximately three feet deep in a 14 feet box) with the majority of its capacity used for storm relief. It was thought that this sewer would be fairly representative of an outlet sample point with regard to the pollutants it would contain during storm events.

Two other factors were considered in the site selection. Since the pump was limited to about 18 feet of lift, it was necessary to locate the pump within the manhole. At the location selected, the manhole



SAMPLE POINT NUMBER	LOCATION	SUSPENDED SOLIDS (MG. L.)	B.O.D. (MG/L.)	TOTAL COLIFORMS PER 100 ML. (IN THOUSANDS)
101	MAIN BRANCH AT EIGHT MILE ROAD	66	5	307
102	EVANS DITCH AT EIGHT MILE ROAD	69	8	170
118	MAIN BRANCH AT FENKELL AVE.	51	7	208
103	UPPER BRANCH AT FIVE MILE ROAD	44	6	163
104	BELL BRANCH AT BEECH DALY	54	6	420
119	MAIN BRANCH AT PLMOUTH	43	8	246
105	ASHCROFT DRAIN AT WEST PARKWAY	47	15	396
106	MAIN BRANCH AT WARREN	45	8	200
107	MIDDLE BRANCH AT HINES DRIVE	46	7	210
108	LOWER BRANCH AT BRADY	41	10	272
120	MAIN BRANCH AT ROTUNDA DRIVE	44	8	266
110	MAIN BRANCH AT FORT STREET	36	7	164

Figure 60- SUMMARY OF ROUGE RIVER SAMPLE ANALYSIS

was built after construction of the box sewer and an access hole was drilled through the crown. A ledge existed in the manhole, and the pump was located on this ledge. Secondly, the manhole was located in a park which allowed easy access without traffic interference.

The sampler was located in a small shed which is shown in Figure 61. The shed was set over an open manhole and chained to the manhole steps to prevent vandalism. The sampler is serviced by a two-man crew and the service van is equipped with a hoist to allow for lowering the sampler into underground locations. The van and hoist are shown in Figure 62 and 63, respectively. The sampler may be operated with 120-volt A.C. or 12-volt D.C. At the location shown in Figure 61, two 12-volt automotive batteries wired in parrel were used to provide the necessary amperage. The sampler and batteries are shown in Figure 64. Since the batteries had to be charged daily, the sampling van was also equipped with a battery charger.

The automatic sampling program was very disappointing. As others have discovered, debris (paper, rags, plastics from disposable diapers, etc.) in the combined sewer tend to wrap around the sampling head and cause blockage (25). Several months were spent on testing different types of protective devices for the sampling head. It was found that a #10 tin can seemed to afford the best protection while at the same time allowing a representative sample to be obtained. Although the plugging problem was not eliminated, it was considerably improved.

Once the plugging problem was lessend , a second major problem arose. An attempt was made to study the variation in pollutional load in the combined sewer during storm events. Figures 65, 66 and 67 are plots of suspended solids concentration versus time. Above each bar graph is a graph of rainfall versus time from a nearby rain gage. As is obvious from the graphs, the sampler did not obtain representative samples of suspended solids. The widening variations in suspended solids was found in almost every day's sampling. Although it would be reasonable to expect variations in suspended solids, the wide variations from 0 mg/l up to 1000 mg/l occurring at random time periods indicate that samples were not representative.

The pump was of the flow inducer type, in which the sample travels through a 3/8-inch plastic tube to a distributor arm in the sampler. The distributor arm traverses a series of holes arranged in an arc pattern and connected to the various sampling bottles. The pump is adjustable from approximately 1/3 gph to 4 gph, depending on sampling time desired. For DMWD's application, it was set at the lower pump rate to provide for a 24-hour sampling period. It appears that this lower flow rate resulted in an accumulation of solids in the sample line and their release into the sample bottle as a "slug". Daily flushing and cleaning of sample lines did not improve this problem.

Figure 61 - SAMPLING SHED AND VAN

Figure 62 - SAMPLING VAN

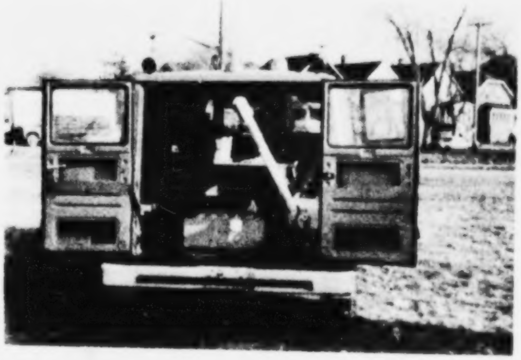


Figure 63 - VAN AND HOIST

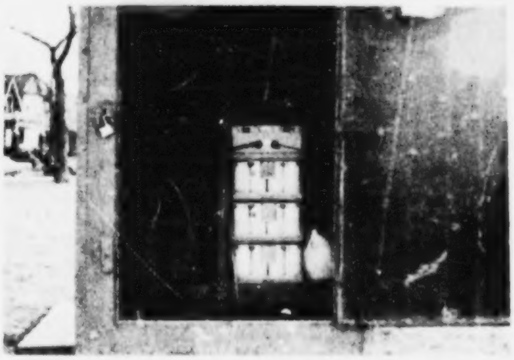


Figure 64 - AUTOMATIC SAMPLER

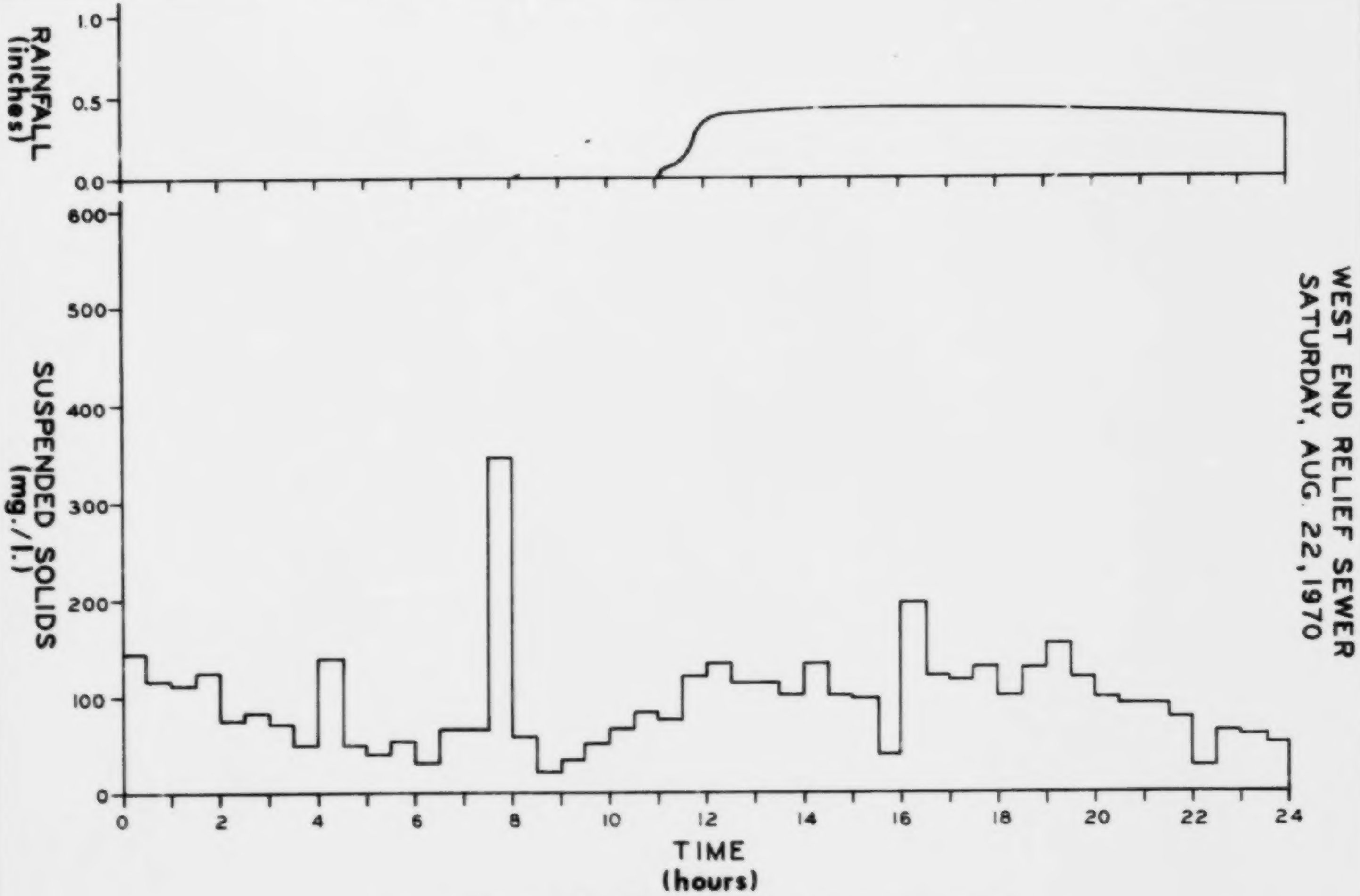


Figure 65-AUTOMATIC SAMPLING RESULTS

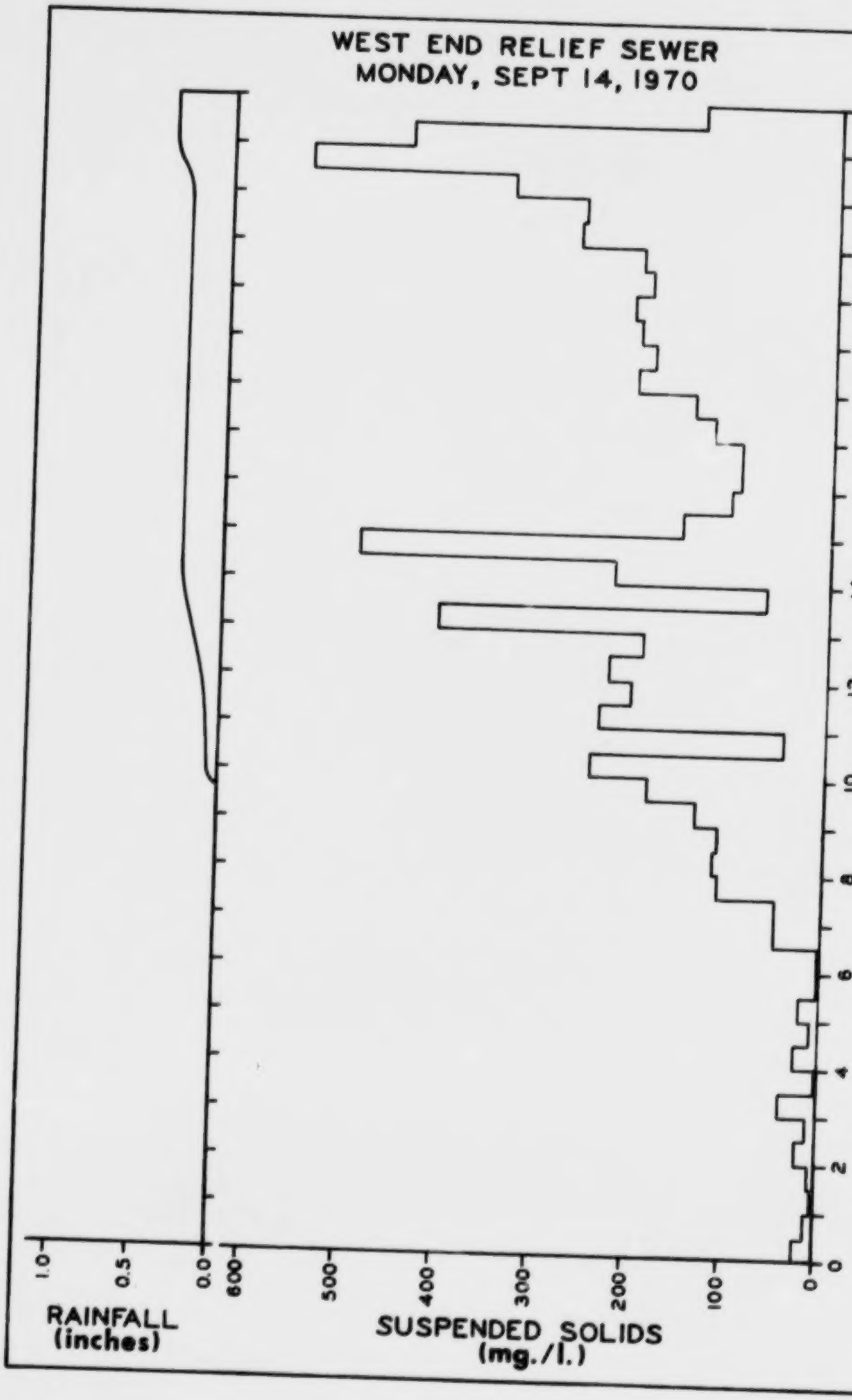


Figure 66-AUTOMATIC SAMPLING RESULTS

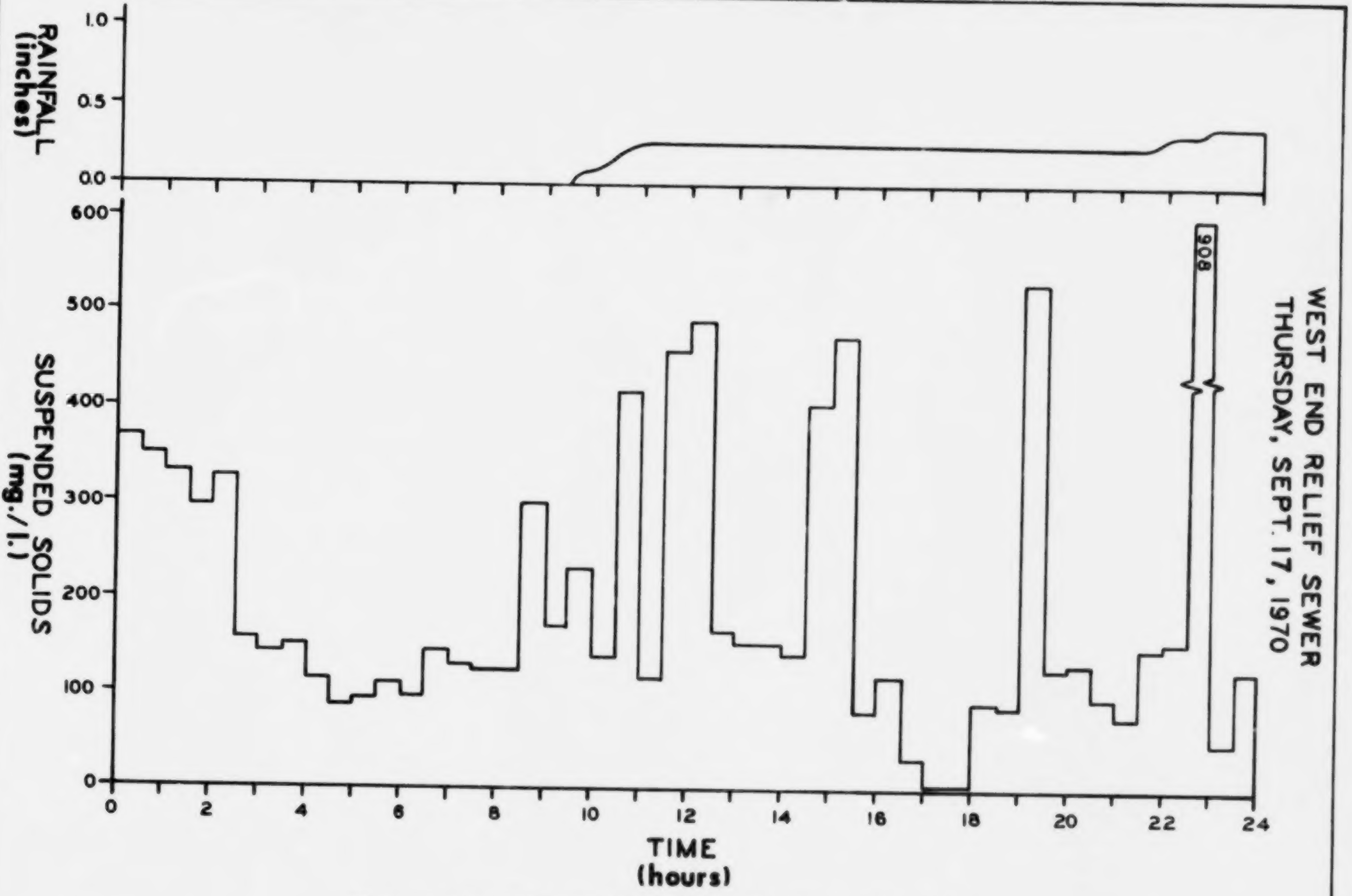


Figure 67-AUTOMATIC SAMPLING RESULTS

Based on DMWD's experience, the concept used by the Megator sampler would provide an ideal collecting device for combined sewer overflows, since it would not only sample the overflow but also give information as to time of overflow. However, the means to transfer the combined sewer sample to the sampling bottles is entirely inadequate. It is recommended that the sample line be a minimum of 1-1/2 inch ID, the pump be a minimum of 25 gpm capacity and that a primary grinder be installed on the sample line. A flow-through type system with a take-off for the sampling device is recommended. To sample combined sewer overflows, the system would have to be equipped with the necessary sensors to detect overflows and to start and stop pumping. It would also require on-site power for the pump and comminutor. Although this system would have limitations as to location, it is felt that if a truly representative sample is desired a large flow must be maintained. With a flow-through system, the sampler could be located away from the manhole. This would be desirable since hydrogen sulfide could damage the equipment. This type of damage did occur to the sampler tested and it was necessary to rebuild the sampler.

SECTION VIII

MONITORING AND REMOTE CONTROL EQUIPMENT EVALUATION

The Concept of system monitoring and remote control with regard to combined sewers is relatively new. Industrial processes and water supply systems have used monitoring and remote control systems for some time. The technology of systems control equipment has increased accordingly in these fields.

Unlike the above systems in which the process flow variations can be predicted and the constitutents of the process flows, in general, are well defined, combined sewer flow is highly variable and the flow may contain any number of chemicals, solids and gases. Thus, many of the system monitoring devices available are not suitable for combined sewer systems (26). Because the Detroit sewer system is so large and complex, other monitoring devices such as sonic level sensors, flumes, acoustic flow meters, etc., are limited in application due to their high cost.

The purpose of this section is to evaluate the system monitoring and remote control equipment installed by DMWD. It is hoped that this evaluation may aid others who are contemplating a similar system.

RAIN GAGES

The main consideration of the installation of telemetering rain gages was the economics of the device to be used. Weighing gages did not offer this economy. Because of the large area to be covered in the rain gage network, it was not practical to install weighing gages that must be emptied manually. Consideration was given to automatic emptying of gages, but it appeared that this would be quite costly. The only practical method would have been to remotely control the emptying procedure since on-site timing devices might empty the device while a rain event was occurring. Thus, economics dictated that tipping bucket rain gages be installed.

The rain gages were installed primarily to aid in operation of the system. They provide the operators with data relative to location and intensity of rainfall as well as the total rainfall. By knowing approximately where it was raining and with what intensity, the operators could take the actions necessary to minimize combined sewer overflows. To this end, they have served their purpose well.

It was hoped that, in addition to operational data, the rainfall data could be used for analytical studies relative to runoff characteristics and system response. Before this type of study could be done, it was necessary to analyze the accuracy of the telemetered tipping bucket rainfall data. For this reason, three of the tipping bucket gages were located next to weighing gages which are part of the Southeast Michigan rain gage network.

Approximately 100 rainfall and snowfall events were used in the analysis of the data. It was concluded that the rain gages are not accurate enough for analysis purposes. As in the case of other investigators (27), data transmission was found to be the most significant source of error. The major problem encountered is in the method of data transmission. As was discussed in Section VI, a continuous tone signal is broken momentarily each time the bucket tips. Unlike weighing gages which can be equipped to produce continuous analog signals, tipping bucket gages produce pulse type signals. The computer interprets each signal interruption as 0.01 inch of rain. There is no on-site pulse counter. This has led to two problems. If a pulse is received, there is no means currently available to check whether a valid pulse occurred or whether transmission line noise was creating erroneous pulses. Secondly, if the transmission line is down, there is no means available to store information locally until it can be transmitted. Thus, without some type of on-site pulse counter, it is not possible to provide for transmission checks. It is estimated that the cost of data transmission will triple if accuracy to ± 0.01 inch is desired. This would require extensive software modifications as well as additional on-site data transmission devices.

A second source of error in tipping bucket data is in the measurement of snowfall. Some gages were equipped with 60 watt heaters. However, field observations as well as the data indicated that these heaters were not sufficient to melt accumulated snow. Currently, all tipping bucket gages are being equipped with 500 watt heating tape to maintain 45°F temperature.

It is believed that, with the installation of the heaters and more sophisticated data transmission devices, the tipping bucket gages will provide data which is sufficiently accurate to be used for analysis (28).

LEVEL SENSORS

Because of the large number of level sensors installed, 118, and the planned future expansion to about 250 level sensors, it was realized that the installation of bubbler type level sensors would be highly impractical. Instead, air bellows type sensors were designed and installed. These have proven to be reliable and almost maintenance-free. With the exception of wet wells and several sewers that can surcharge, it has been found that the bellows unit could be changed from 0-40 feet full scale to 0-20 feet full scale. This increase in sensitivity would be desirous but does not appear to be justified at this time.

It was decided to purge the gages bi-yearly with compressed air as routine maintenance precautions. Some gages, however, have been in operation for over two years without any maintenance and continue to perform satisfactorily. To date, very few of the sensors have been plugged with either debris, oils or grease. Other pressure cell installations in the area using stainless steel have been blocked with grease. It appears that PVC pipe is much less subject to grease accumulation than other materials.

The original plan for sensor installation did not call for the use of conduit to enclose the 1/4-inch nylon tubing but it was included at the Environmental Protection Agency request. This has proven to be a wise decision since it allows for the replacement of the tubing with a minimum of such problems as traffic disruption. There have been a few locations where the conduit has buckled out of the slot in the pavement due to heavy traffic loads. To eliminate this problem in later installations, the conduit has been cut and a sleeve, designed to allow for local expansion and contraction has been placed approximately halfway between the manhole and the curb. This additional change has allowed the necessary movement required to keep the conduit from buckling because of traffic loads.

It has been found that once the 1/4-inch nylon tubing has been cut or if a leak should develop, an effective air tight splice is difficult to achieve. One tube was cut with a pavement breaker and attempts at splicing failed. The current procedure requires that the entire length of tubing from the level cell to the valve inside the pedestal cabinet be replaced.

With the large number of sensors and diversity of location throughout the city and suburbs, it was thought that vandalism and traffic accidents would be a problem. Sensors have been in operation for over two years and, to date, only two have been lost due to vandalism and one due to an auto accident. This fact has eliminated many anticipated problems.

Periodically, sensors are recalibrated. Figure 28 shows the level indicator in the pedestal. Note the embossed tape. It contains the sensor number, sensor height above invert and the depth to invert.

The recalibration procedure first calls for the injection of compressed air into the 1/4-inch nylon tube and the connected cell in order to clean out any foreign material which may be in the level cell assembly. Next the depth of flow is measured and the height at which the cell is located above the invert is subtracted from this measurement. The tone signal corresponding to this difference is what should be transmitted to System Control. A call is placed to the System Control Center where a readout is requested on the monitor. Adjustments are made to the air bleedoff valve and to the linkage until the reading at System Control is identical to the measured reading. Calibration when needed has been found to be a relatively simple procedure.

A number of variables were analyzed to determine their effect on the accuracy of the level sensors. These included: variations in barometric pressure, air and wastewater temperature and wastewater density; soluability of air in water; gases produced in the wastewater; and transmission line noise.

The level sensors are designed to measure gage pressure, not absolute pressure. Since both the equipment cabinet and sewer manholes are not sealed, any difference in barometric pressure acting on the components of the measuring system is due to the difference in elevation between the wastewater surface and the bellows. However, this difference in elevation has a negligible effect on the level measurement.

Seasonal variations in the wastewater temperature and the resulting change in density affect readings by less than ± 0.2%. This was based on the assumption that the temperature of the wastewater varies between 40°F and 80°F and that the specific weight of the wastewater is equivalent to that of water for the temperature range shown.

The effect of air temperature on the level sensing equipment was evaluated during an extremely cold period in December, 1968. A regulator on one of the sewers was manually adjusted to cause wastewater level changes. Temperatures as low as -6°F caused no measurable effect on the sensor reading or data telemetering. All of the level sensor cabinets are equipped with heating elements to maintain the temperature above 45°F. In addition, the air bellows are designed to maintain linearity over wide temperature ranges.

The diffusion of the air in the cell into the wastewater, or the releasing of gases into the system from the wastewater affects the volume of air in the level cell-bellows system. In addition, the coating of the inside of the cell with waste material will also affect the air volume. As the volume of air in the cell decreases, the wastewater must rise higher in the cell. Assuming that, in the worst case, the air volume is halved, and that the air in the system obeys the perfect gas law, $pv = RT$, the resulting error in level measurement will be less than -0.05 feet. Increases in air volume will cause positive errors in level measurement of the same magnitude as decreases.

Transmission line noise has not been found to be a major problem at the present time (29). Signals are generated using a cam follower contact. Existing sensors are designed for 5-second cycle time for data transmission. Due to wear and motor maintenance, it is planned to install 15-second cycle on all new sensor points. Currently, the system prints out a real time reading based on the latest 5-second interval. All other previous readings are ignored. The level in the sewer is printed out to the nearest 0.1 foot which is equivalent to a 7.5 millisecond signal duration. Several sensors were installed at a height above the sewer invert such that they rarely transmit a signal to indicate rising levels. A pre-programmed constant is added to the level sensor reading by the computer to account for height of sensor above the invert. With the exception of major storms, the data printed has never been higher than this constant. If line noise were a problem, one would expect a reading to be affected occasionally. This has not been the case.

With the data available at this time, and considering the variables which can affect level sensor measurements, it appears that the level sensor data is accurate to ± 2% in the worst possible combination of the above. In general, accuracy to ± 1% would be expected.

STATUS SENSORS

Two types of status sensors are used to determine when combined sewer overflows into the Detroit and Rouge Rivers are occurring. Wherever possible, backwater gate proximity sensors are used. In locations where this was not possible, probe type dam overflow sensors are used.

One problem common to both types of sensor has been at locations where there are multiple gates or dams. It has been found that in several locations, only one of several backwater gates has opened, and the open status was not recorded due to the fact that the monitored gate did not open. In order to monitor all gate openings, sensors will be installed in series on multiple gate and/or dam locations. Although this will not allow the monitoring of each gate individually, it will indicate overflows occurring at a given location.

Proximity Sensors

Proximity sensors have yielded excellent data regarding backwater gate status. To date, there have been negligible maintenance problems even though many of the devices have been submerged continuously.

Two problems have been encountered, however. Wave action has yielded false readings. This has been eliminated where tandem gates exist and the sensors were remounted on the upstream gates. Line noise has also given false readings. Computer software is designed to neglect signal changes that occur in 15-second intervals or less. This has reduced the majority of false readings. It has also been found that the transmitter must be periodically checked to insure that full signal strength is maintained. As the signal weakens, line noise tends to affect signals to a greater degree.

Electrode Sensors

Several problems have been encountered with the electrode probe installations. Due to the geometry of the sensor as shown in Figure 32, there has been a tendency for debris to accumulate in the casing and cause erroneous overflow indications. Several sewers which contain a high amount of grease have caused considerable maintenance problems as the grease tended to harden within the protective casing. Rags, plastic sheets and paper have also been found to create problems by wrapping around the electrodes. Although the protective conduit was designed to allow flushing, it has been found ineffective in some instances. Ice bridges and condensation have occasionally caused false readings.

From experience with the electrode installations, all future installations will call for separate protective conduits for each electrode. Minimum spacing of electrodes should be at least four inches so that the larger debris cannot cause false readings. In addition, electrodes should be easily adjustable in height. At certain dams, flashboards have been installed to raise dam height. It has proved difficult to adjust the electrodes.

COMPUTER SYSTEM HARDWARE AND SOFTWARE

In its initial conception, the data acquisition system was to be used as an aid in the remote operation of the pumping stations and to acquire data relative to the response of the combined sewer system during storm events. It was not intended to process data in any manner other than to provide hard copy output on the data loggers and to annunciate programmed alarm conditions via the teletypewriter.

For process control applications, a backup computer is usually installed. However, because of the complexity and size of the Detroit combined sewer system, it was decided that before any computer control of the system could be implemented, system response to storm events would have to be well documented in order to define the appropriate mathematical model. Various studies on predicting system response and the related problems inherent to such mathematical models require large computer systems (27, 30, 31). Also, since the sensor based data acquisition system was experimental in nature, it was not deemed advisable to control the sewer system until sensor reliability could be determined. For the above reasons, a small computer designed for data acquisition purposes was installed. As a backup to the computer data acquisition system, scanners have been placed at all remotely operated pump stations and sluice gates. The scanners monitor various equipment as to whether the equipment is properly operating at each location. In addition, wet well levels and selected upstream level sensor data are displayed on the control panels independent of the computer via strip chart trend recorders. This backup system has proved invaluable since the computer has been down several times since its initial installation. Although some information was lost, pump station operations were not affected to any great extent.

As with most computer installations, system startup was not without problems. Hardware problems included failure of transistors, loss of memory due to variations of line voltage and calibrating the telemetered signal to correspond with the data logged. Once these problems were solved, data output became quite dependable.

All programming for the computer must be done in an octal based machine language. This type of programming is unfamiliar to many programmers, and has hindered development of new programs. Also, since there is no foreground-background capability or backup computer, it is not possible to test program changes prior to implementation on the on-line system. Thus, only minor programming changes have been made.

DATA LOGGING

There are several limitations to the data logging system that have created difficulties in the analysis of data and in operations. The alarm teletype is quiet noisy when in operation. This has proven to be very useful since it not only alerts the operators to alarm conditions but also prints out the source of the alarm. The data logging typewriters are also quite noisy when printing. However, it has been found that the operators tend to suppress printouts of data to reduce noise levels. Normally, the data is suppressed if a rain cycle (15-minute printout interval) is initiated due to a false rain indication signal. It has also been found that operators tend to suppress printout of data on the 5-minute or 15-minute cycle following the passage of storm. Although the data is no longer needed for operations, it would be useful for analysis in determining optimal system dewatering procedures. The installation of magnetic storage media capable of recording data on a 5-minute cycle for up to 24 hours after a storm would eliminate this problem.

Level Sensor Data

Figure 68 is a portion of the output from Data Logger No. 1 and also a portion of the index sheets which is used as a key to identify sensor points. The output shown represents various levels in the sewer system and on the Rouge River. Two sewer level sensors, A-5 and 20, were out of service and river sensor, A-40, was jammed with debris. This particular data set was selected in order to show the various print cycles.

The print cycle was initially at 15-minute intervals. This indicates that rain was being recorded but no alarm levels at any point in the sewer system had been reached. The print cycle shifted to 5 minutes for one data set, indicating alarm levels. It then shifted back to a 15-minute cycle. Note that hourly cycles are always logged. The rain stopped at about 6:30 a.m. and the logging shifted back to the normal hourly print cycle.

Although the output may look somewhat confusing, it has been found that experienced operators have little trouble in finding the appropriate sensor output. The data could be much more easily read if only one line was used for each real time printout and each point was identified on the logger platen. However, the amount of data printed would not allow a one-line printout in the space available for data loggers.

INDEX TYPEWRITER #1

MO DAY YR	HOUR MIN SEC	20 / A-33	A-38 / A-10	A-39 / A-11	A-40 / A-9	A-8	A-7	A-6	A-5	A-4	A-3	A-2	A-1	A-12	A-13	A-14	A-15
06.29.71	05.30.03	02.2	01.2	02.7	05.7	05.8	11.6	06.0	00.0	09.2	09.3	08.8	07.4	02.3	04.0	05.6	02.7
		00.0	01.8	04.2	20.8												
06.29.71	05.45.03	02.1	01.0	02.3	05.8	05.9	11.3	05.9	00.0	09.8	09.7	09.4	07.9	02.2	04.0	05.4	02.7
		00.0	01.8	04.2	20.8												
06.29.71	05.50.03	02.1	01.0	02.5	05.8	06.2	11.4	06.1	00.0	10.1	09.8	09.5	08.1	02.5	04.0	05.6	02.7
		00.0	02.0	04.2	20.8												
06.29.71	06.00.03	02.2	01.0	02.7	06.1	06.0	11.3	06.2	00.0	10.1	10.3	09.8	08.4	02.5	04.0	05.9	02.7
		00.0	01.8	04.2	20.8												
06.29.71	06.15.03	02.1	01.0	03.4	06.5	06.5	09.1	06.7	00.0	11.0	10.8	10.4	08.7	02.8	04.0	06.3	02.9
		00.0	02.0	04.2	20.8												
06.29.71	06.30.03	02.3	01.1	04.0	07.2	07.0	11.3	07.8	00.0	11.4	11.4	11.0	09.1	03.2	04.0	06.5	02.7
		00.0	01.8	04.2	20.8												
06.29.71	07.00.03	02.2	01.0	05.6	08.3	08.1	18.4	09.5	00.0	11.8	12.1	11.8	10.8	05.3	04.0	08.8	02.7
		00.0	01.8	04.2	20.8												

Figure 68-LEVEL SENSOR DATA

For certain key sensors on the interceptor and near pump stations, embossed tape has been placed on the data logger platens to aid operators.

CRT displays and high speed printers are being investigated as additional output aids to the operator. Preliminary studies have indicated that the most useful form of display would be CRT's. Operators have indicated that CRT output should include a schematic diagram of the sewer plan and level sensor locations with pump station location, if applicable, together with alphanumeric level display. It has also been suggested that multicolor CRT's be used. Rising levels, falling levels, and alarm levels could be indicated by various colors. If data logging or alarm printing is replaced by CRT's, there is still a necessity for audio alarms to insure that operators are alerted.

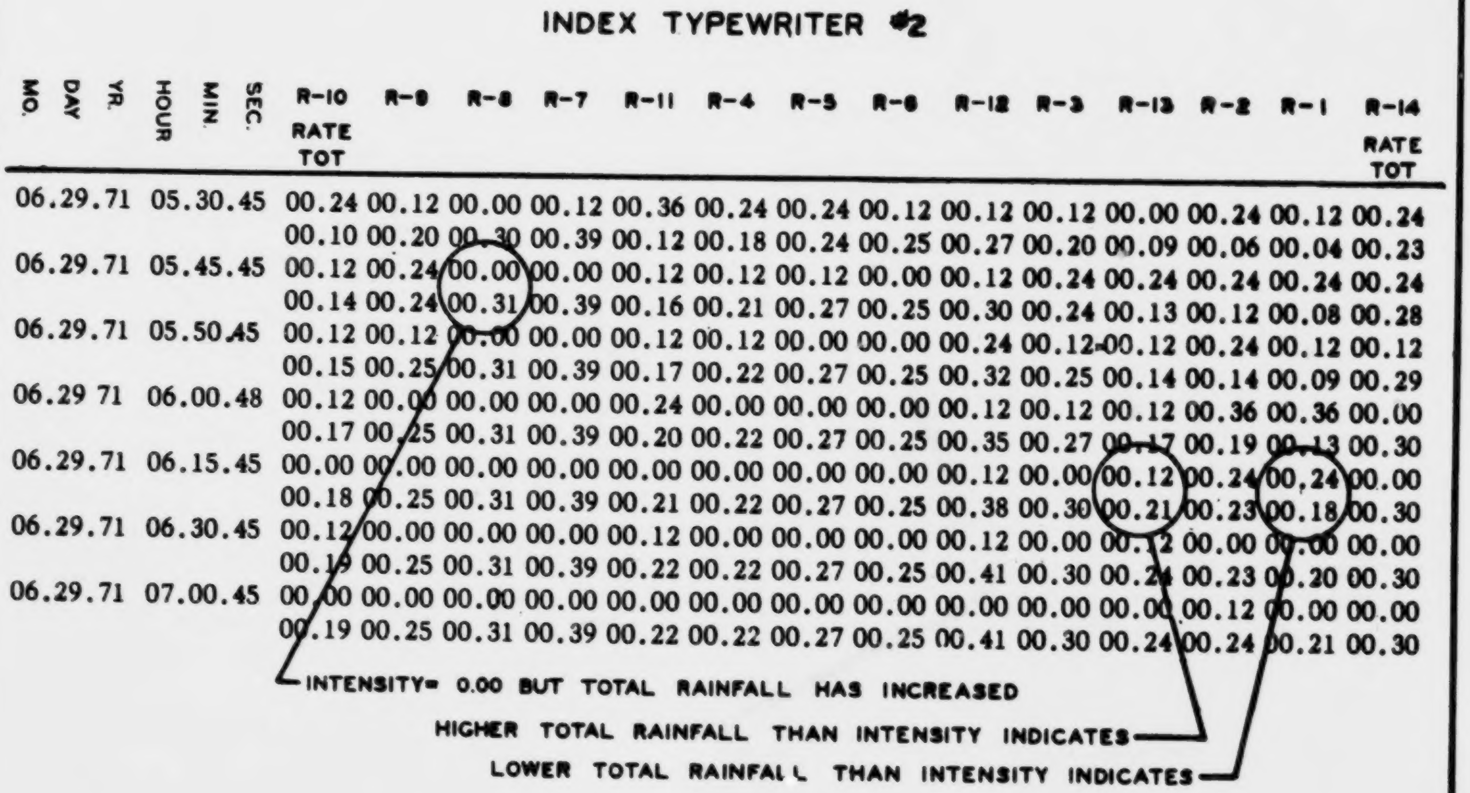
Rain Gage Data

Figure 69 shows the rain gage data output for the same day and time. Two lines are required for output. The first line shows the intensity over the preceding 5 minutes and the second line shows the total rainfall. The index sheet is shown above the data. One problem in the software is evidenced by this data. Printout is either 5, 15 or 60 minutes apart depending on the print cycle. Rainfall intensity, however, is based on a 5-minute cycle. Thus, the intensity shown in the output is for the preceding 5 minutes only. Referring to the data, it can be seen that at times during a 15-minute cycle, the intensity is 0.00 while total rainfall has increased. At other times, the intensity indicates that total rainfall should be higher or lower than that shown if calculations are based on the 15-minute cycle shown. Although this has not created any operational problems, it would be more convenient if intensity was based on the print cycle time rather than the preceding five minutes.

Overflow Status Sensor Data

The overflow sensor data is shown in Figure 70. The period selected corresponds to the real time shown for the level sensor and rain gage data. As in the case of level sensor and rain gage data, an index sheet is used to identify the various sensor points. A portion of this index is shown above the data. The numeral "1" in the data indicates that no overflow is occurring while the numeral "0" is used to indicate overflows.

Status sensor printout follows the same cycle as level sensor and rain gage sensor printout. This can be seen by noting the printouts at approximately 5:30, 5:45, 5:50, 6:00, 6:15, 6:30 and 7:00 which correspond in time to the level sensor and rain gage printout times. There is approximately a 2-minute interval between the start time of print of level sensor data and the start time of print of overflow sensor data. Thus, the cyclic times shown in this data lag the times shown for level sensors. The rain gage real time lags the level sensor time by approximately half this amount. The lag times are due to the print time required



INDEX TYPEWRITER #2

MO. DAY YR.	HOUR MIN. SEC.	R-10 RATE TOT	R-9	R-8	R-7	R-11	R-4	R-5	R-6	R-12	R-3	R-13	R-2	R-1	R-14 RATE TOT
06.29.71	05.30.45	00.24	00.12	00.00	00.12	00.36	00.24	00.24	00.12	00.12	00.12	00.00	00.24	00.12	00.24
		00.10	00.20	00.30	00.39	00.12	00.18	00.24	00.25	00.27	00.20	00.09	00.06	00.04	00.23
06.29.71	05.45.45	00.12	00.24	00.00	00.00	00.12	00.12	00.12	00.00	00.12	00.24	00.24	00.24	00.24	00.24
		00.14	00.24	00.31	00.39	00.16	00.21	00.27	00.25	00.30	00.24	00.13	00.12	00.08	00.28
06.29.71	05.50.45	00.12	00.12	00.00	00.00	00.12	00.12	00.00	00.00	00.24	00.12	00.12	00.24	00.12	00.12
		00.15	00.25	00.31	00.39	00.17	00.22	00.27	00.25	00.32	00.25	00.14	00.14	00.09	00.29
06.29 71	06.00.48	00.12	00.00	00.00	00.00	00.24	00.00	00.00	00.00	00.12	00.12	00.12	00.36	00.36	00.00
		00.17	00.25	00.31	00.39	00.20	00.22	00.27	00.25	00.35	00.27	00.17	00.19	00.13	00.30
06.29.71	06.15.45	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.12	00.00	00.12	00.24	00.24	00.00
		00.18	00.25	00.31	00.39	00.21	00.22	00.27	00.25	00.38	00.30	00.21	00.23	00.18	00.30
06.29.71	06.30.45	00.12	00.00	00.00	00.00	00.12	00.00	00.00	00.00	00.12	00.00	00.12	00.00	00.00	00.00
		00.19	00.25	00.31	00.39	00.22	00.22	00.27	00.25	00.41	00.30	00.24	00.23	00.20	00.30
06.29.71	07.00.45	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.12	00.00	00.00
		00.19	00.25	00.31	00.39	00.22	00.22	00.27	00.25	00.41	00.30	00.24	00.24	00.21	00.30

INTENSITY= 0.00 BUT TOTAL RAINFALL HAS INCREASED

HIGHER TOTAL RAINFALL THAN INTENSITY INDICATES

LOWER TOTAL RAINFALL THAN INTENSITY INDICATES

Figure 69-RAIN GAGE DATA

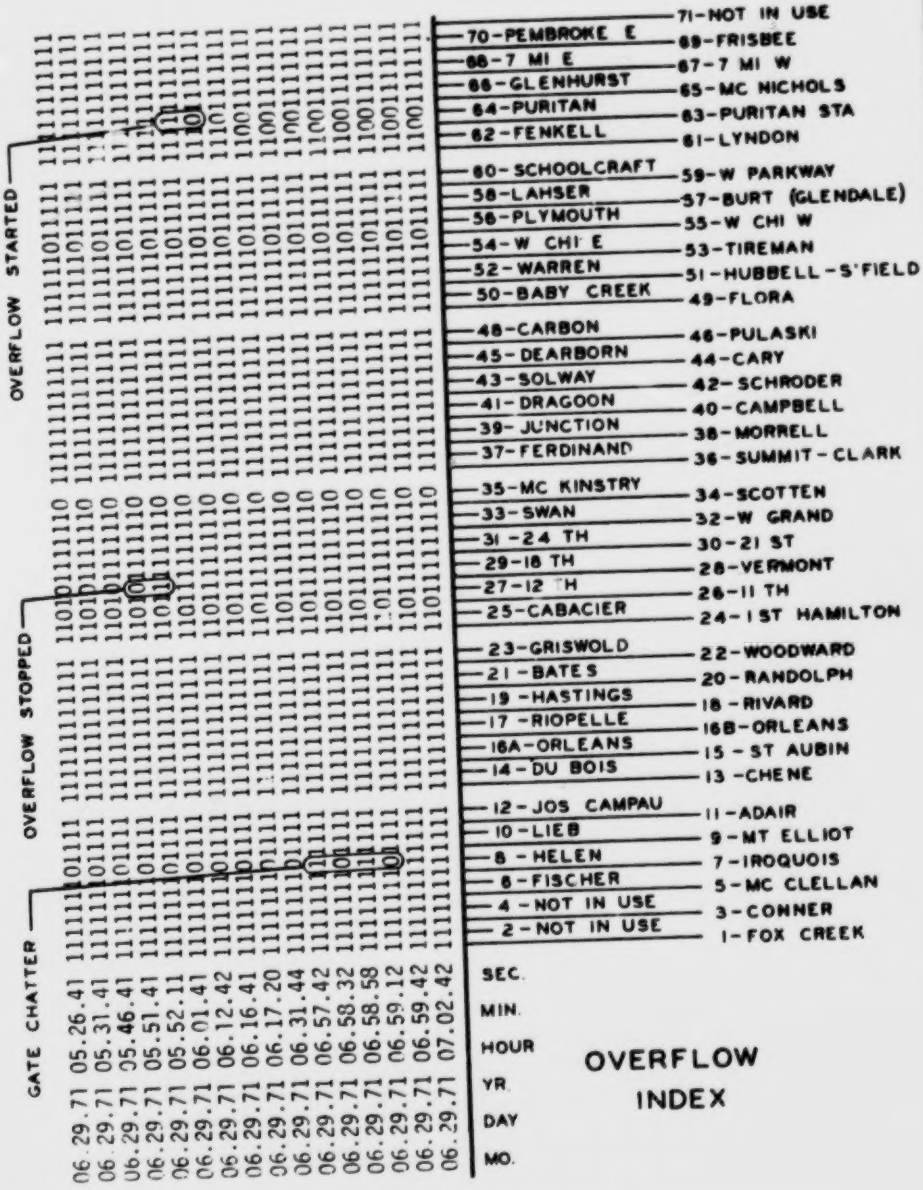


Figure 70 - OVERFLOW STATUS SENSOR DATA

for each data set. In addition to the standard cycle times, status sensor data is also printed whenever a change in status is recorded. An overflow start and an overflow stop are indicated on the data selected to illustrate this additional printout.

The major problem associated with the logging of overflow status sensor data has been "gate chatter." Gate chatter is perhaps a misnomer, but in this report it is used to describe a condition in which the data logger output indicates a series of gate openings and closings within a short period of time. This can be seen in the data set where four overflow starts and stops occurred within approximately one minute. This is believed to be due to river wave action, sewer surges or transmission line noise or combinations thereof. The result is that a large number of data sets have been logged.

To reduce the number of printouts, computer software was modified to check overflow status at the beginning and end of a 15-second time interval. If the status change signal is received, a status change is logged. Software is being modified to check status continuously over a two-minute interval. If the status remains the same, it will be logged. If gate chatter is occurring, the total time of chatter will be stored internally and printed out at the end of the day. This should reduce the number of data sets logged, while at the same time provide a summary of total chatter time. The summary can then be used to check for the cause of the chatter.

SUPERVISORY CONTROL SYSTEM

Pump Stations

DMWD was well experienced in the remote operation of pump stations. The water distribution system has been remotely controlled since 1962 and to date no major problems have arisen in that system. Several of the suburban communities which have sewage pump stations expressed interest in remote operation of their own facilities but were hesitant to do so. Various concerns were expressed such as station fires and impeller or shaft failures which may go undetected. One community investigated the possibility of installing closed circuit television but found the cost prohibitive. This was mainly due to the length of coaxial cable required. With the monitoring equipment available, it is basically a question of economics as to the degree of sophistication in equipment and decisions as to what parameters are most critical.

Monitored pump station parameters at the DMWD Systems Control Center include transmission line failure, power failure, control channel failure, supervisory equipment failure and station alarm. These conditions are displayed on the control panel as shown in Section VI, Figures 38 & 39. The station alarm may include bearing cooling water loss, high motor and transformer temperature, excessive motor vibration, low voltage, loss of station ventilation, DC power supply loss, combustible gas detection, and high wet well level. Although this alarm system does not include all the potential sources of concern, it does include the more important parameters.

An additional aid to station monitoring has been the strip chart recorders. As mentioned in Section VI, these are used to record wet well levels. They are also used by the operators as an indication of pump operations. The rate of rise or fall in wet well elevation gives an indication of increasing or decreasing flow. The effect on the rate of change of level when a pump is turned on or off is also known to some extent. Thus the operators, through experience, know if a pump is not operating correctly. This was evidenced at one pump station where the impeller was badly worn. Although this pump was rated at the same capacity as other pumps at the station, it did not produce a comparable rate of change of wet well level. The maintenance crews were dispatched to the station and determined that the impeller would have to be replaced.

Sluice Gate Operators

As in the case of pump stations, DMWD had some experience with remote operation of gates and valves in the water system. Both hydraulic and electric gate operators were used in the wastewater system. The choice of whether to install hydraulic or electric systems depended on available space and existing equipment.

In the initial conception of operational procedures, it was believed that all gates would be fully open or fully closed. For this reason, no gate position indicators were installed. Gate status, either "open", "closed", or "running" is indicated on the select-push indicating control switches. It has been found desirable to operate gates at partially open positions. Since the total time of travel from fully open to fully closed is known, the operators are able to set the gates at intermediate positions.

When the desired mode of operation is for partial gate opening, the electric operators are much better. Since travel time is slower, more accurate setting can be obtained. The main advantage of the electric operators is that once a gate is positioned, it will not drift. Hydraulic cylinders, on the other hand, do tend to drift. This problem was of particular concern at the Warren-Pierson Regulator where drifting of the gate would cause dry weather flow to overflow into the Rouge River. For the partial operation of hydraulically operated control equipment, gate position indicators would be highly desirable. Unlike electric operators which can be equipped with rheostats to give gate position, hydraulic cylinders must be equipped with some type of mechanical linkage. DMWD is currently investigating position indicators of both the electrical contact switch type and Metritape position transducers. The effects of the sewer environment on these two positions indicating devices will be of primary concern.

All of the gear boxes on the electric operators ae equipped with manual operators that may be used to raise or lower gates in the event of power loss or motor failure. The hydraulic systems do not lend themselves to this type of manual control. Unless a counterweight mechanism was installed, a mobile crane would have to be used to lift some of the large gates in the event of cylinder failure. In the event of power failure, hand pumps may be used to actuate the cylinder.

At the present time, hydraulic cylinders are used only to control regulators. If a major failure was to occur, the wastewater would overflow into the receiving streams. Although this is not desirable, it does provide a safety factor in that the system will not be affected to the extent of flooding. For in-system storage, it is believed that hydraulic cylinders may not provide a sufficient degree of safety to warrant their use. Electric operators can be equipped in such a way that a single individual can manually operate the gate in an emergency. This is not true of the hydraulic cylinders. In locations where the electric operators may be subjected to an explosive environment or to submergence, it would be better to either bear the cost of sumbersible, explosion proof operators or to build a separate equipment vault for the operators rather than install the intrinsically safe hydraulic cylinder with their poor emergency operability.

Conner Flushing Gates

The effectiveness of the flushing gates will be discussed elsewhere in this report. However, one mechanical problem which may have limited their effectiveness was noted on a recent inspection. It was found that the gates were not closing completely. This was allowing significant flow to pass under the gate which, of course, would reduce the flow to the barrel that was being flushed. It was a simple matter of adjusting the limit switches on the electric operators to resolve this problem.

A second problem did not become apparent until after several months of operations. The flushing gates are equipped with a control system designed to recycle the closing procedure if the gate should become jammed. One of the essential elements of the system was a spring which held an armature tight against the cable as shown in Figure 48. If the cable becomes slack before the gate seats, the spring connected armature would trip a limit switch causing the gate to reverse its direction of travel. It was found that the spring was not holding the armature tight against the cable and thus tripping the switch. The steel spring originally installed was replaced with a stainless steel spring. However, again after several months, the device malfunctioned. The linkage system was replaced with a proximity sensor switch. No problems were encountered after this change.

SECTION IX

OPERATIONS EVALUATION

Detroit has long been interested in pollution control. Its Wastewater Treatment Plant, constructed in 1939, was one of the first large municipal plants in the country. Naturally, in the interest of pollution control, the DMWD was anxious to implement the monitoring and remote control program as soon as possible. This, however, made analysis difficult. Rather than operate the wastewater collection system during storm events in an identical manner to the way it was operated before the implementation of the monitoring and remote control program, the DMWD immediately embarked upon its storm capture and flow routing procedure. Although this was good for the environment, it did not provide any base data which was needed to determine the improvement on reducing storm runoff overflows due to the new system. As could be expected, a three-month study to gain base data by operating the system by the old, fixed point methods of storm pumping produced one of the driest three-month periods in weather bureau history. Information from this test period is minimal indeed.

OVERFLOW REDUCTION

However, analysis has been done on the improvements accomplished due to an increased understanding of system capabilities. The assumptions were made that: 1) a certain amount of time was necessary for the operators to familiarize themselves with the system control concept of operations; 2) determining the full potential of the system was a trial-and-error process -- a time-consuming procedure; and 3) several months of field investigation were necessary to test data reliability. Therefore the data collected from the first six months of operations, along with the data from the three-month test period, was compared to the data collected during the last six months of the demonstration period.

Data used in analysis comprised the number of points at which an overflow occurred, the total number of gallons storm pumped to the river, the duration of the rain and the Equivalent Uniform Depth (E.U.D.) of the rain as determined from the telemetered rain gage data. Because the rate of runoff is highly dependent upon the intensity of the rainstorm and the total amount of rainfall, it is essential that only similar rainfall occurrences be compared. As expected, the number of such occurrences over this brief period is not large. Table 5 is a summary of the pertinent data collected and analyzed for the cases which adhere to the above criteria. The word "no" in the row labeled "Was System Used to Capacity?" reflects operations during the first six months of operation and the three month test period. The word "yes" reflects operations during the last six months of the demonstration period.

TABLE 5

OVERFLOW COMPARISON FOR SELECTED STORMS

	CASE I		CASE II		CASE III	
Date	4/21/70	7/30/71	5/19/71*	7/05/71	3/04/70	8/10/71
Storm Duration (Hours)	6	5	3.5	4	12	8
Rain E.U.D. (Inches)	0.24	0.28	0.69	0.64	0.97	0.93
Was System Used to Capacity?	No	Yes	No	Yes	No	Yes
Number of Overflows	13	4	29	18	30	25
Million Gallons Pumped	---	6.7	75.3	---	126.7	72.7

*Test Period

CASE I: The 7/30/71 storm was more intense and of greater E.U.D. than the 4/21/70 storm. This would suggest a higher amount of runoff. Although there was no storm wastewater pumpage for the earlier storm (compared to the 6.7 million gallons pumped for the later storm), there were 13 points at which overflow occurred. With the Detroit relief points ranging up to two barrels of 14'- 6" x 17'-6" dimensions, it is better to have a short duration pumpage than a number of longer duration overflows. Although the 6.7 million gallon pumpage appears large, it represents less than a four-minute pumpage at the Freud Pumping Station.

CASE II includes the only storm during the three-month test period. During this May 19, 1971, storm, the pump stations were activated strictly because of high wet well levels. System pumpdown, system storage or flow routing were not used. A comparison of the storms themselves show that the test storm was slightly greater in E.U.D. and of a 1/2 hour shorter duration. This would not account for the large difference in overflow parameters. By using the storm anticipation and storage techniques that the DMWD devised, the number of overflows were reduced from 29 to 18 (38%) and the storm wastewater pumpage went from 75.3 million gallons to zero. This is a significant demonstration of the effectiveness of system monitoring and remote control.

CASE III is another indication of improvements gained through experience. Although the storms dropped an almost equal amount of rain, the latter storm was of much shorter duration. Thus it would be expected that there would be more runoff and hence more overflows and pumpage during the latter storm. However, the number of overflows were reduced and the storm wastewater pumpage was 53 million gallons less. Both storms dropped a substantial amount of rainfall and, even though overflows were reduced a significant amount, there was still more storm wastewater pumpage and a greater number of overflows than is desired.

Another indication of the successful efforts using the monitoring and remote control program has been in the amount of rainfall completely captured within the sewer system. In the first six months of the program, the largest rainfall which the DMWD was able to completely contain (no overflows and no storm wastewater pumpage) had an E.U.D. of 0.07 inches over Detroit's 137.89 square miles. In the last six months of the demonstration period, the DMWD was able to contain a rainfall of 0.14 inches E.U.D.

STORM WASTEWATER PUMPAGE REDUCTION

Figure 71 is a graphical depiction of the improvement in storm wastewater pumpage to the river due to the monitoring and remote control program. In 1968 before the project was initiated, storm pumps were started if the wet well level rose beyond a certain fixed point as previously discussed. It was believed that pumping to the river was less detrimental than running the risk of flooding portions of the city.

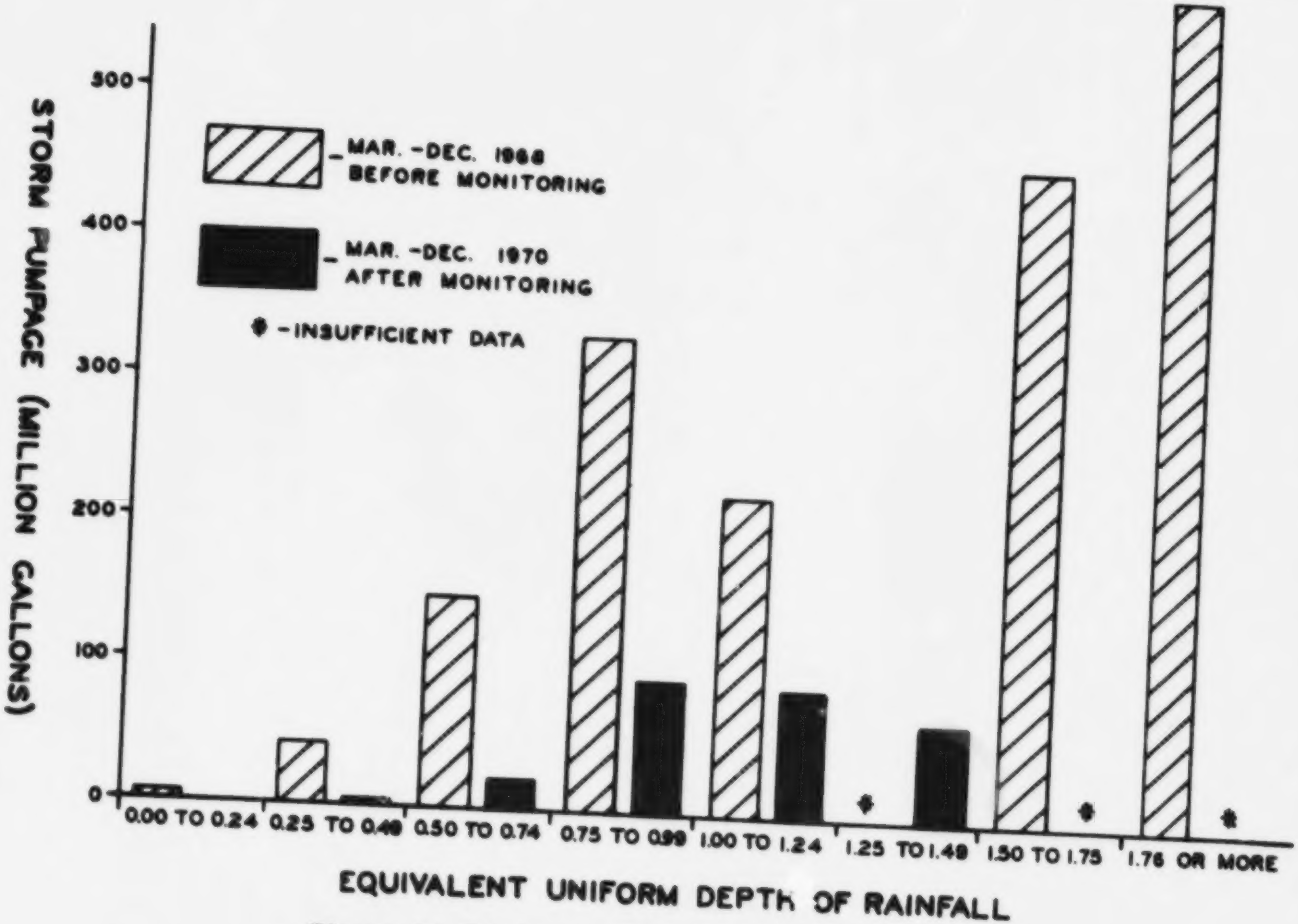


Figure 71-E.U.D. vs. STORM PUMPAGE

By 1970, the storm wastewater pumping stations' mode of operation was changed to conform to the monitoring and remote control concept of operation.

All rainfall in the study period was segmented into 1/4-inch intervals. The number of rainfall events in each interval was tallied along with the amount of storm wastewater pumped to the river as a result of the rainfall. The average amount of storm wastewater pumpage which was likely to occur for a rainfall of a given size was determined. The total rainfall was the only criteria; storm intensity, moisture content of the soil, temperature and other factors affecting the amount of runoff likely to occur were not included in the analysis. By examining Figure 71, it is obvious that there was a substantial reduction in the amount of storm wastewater pumpage resulting from the project. However, because total rainfall was the only criteria for rainfall grouping, the exact amount of reduction could not be determined. Note that some of the storm wastewater pumpage volumes for E.U.D.'s greater than 1.25 inches are not shown due to lack of data.

A frequency distribution for the rainfall in 1968 and 1970 along with the number of pumpage events and the average amount of storm wastewater pumped to the river for each rain appears in Table 6. It is important to note that before monitoring, storm wastewater pumpage occurred for every rain in excess of 0.50 inch. After monitoring, the activation of the storm wastewater pumping stations was no longer a necessity for a rainstorm of this magnitude, and on one occasion the DMWD was able to sustain a 1.35-inch rainfall event without storm wastewater pumpage.

IN-SYSTEM STORAGE VOLUMES

A sufficient amount of data has been assembled to calculate the minimum volume of storm wastewater which was stored in conjunction with the monitoring and remote control program. The actual total volume of storm wastewater stored would be difficult to determine due to the fact that storage occurs many miles upstream of any regulator structure which is set for storm wastewater capture. Thus, only the major portions of the sewers near the outfalls were used in the volume determinations.

The data used for volume determination was a combination of pump station records, sluice gate operation records, level cell data and sewer hydrograph-analysis. Some locations of large potential storage volumes were used only for large storms and consequently did not have a correspondingly large amount of captured storm wastewater. This is evident at the Freud Pump Station. Other locations are of relatively small volume but are always used in the storm capture procedure and therefore have a correspondingly high amount of retained storm wastewater.

Table 7 lists the amount of storm wastewater captured at each storage location during the 18-month demonstration period. The total volume of

TABLE 6

STORM WASTEWATER PUMPAGE REDUCTION

E.U.D. RAIN (Inches)	NO. OF RAINS MAR/DEC 1968	NO. OF PUMPAGE EVENTS	AVERAGE NUMBER OF GALLONS PUMPED	NO. OF RAINS MAR/DEC 1970	NO. OF PUMPAGE EVENTS	AVERAGE NUMBER OF GALLONS PUMPED
0.00 - 0.24	54	6	---	88	0	---
0.25 - 0.49	18	10	48,500,000	23	2	4,340,000
0.50 - 0.74	4	4	134,500,000	9	4	20,800,000
0.75 - 0.99	3	3	329,100,000	4	3	92,200,000
1.00 - 1.24	4	4	221,800,000	1	1	82,800,000
1.25 - 1.49	0	--	---	3	2	67,100,000
1.50 - 1.74	2	2	467,900,000	0	--	---
1.75	3	3	609,200,000	0	--	---

TABLE 7

RUNOFF CAPTURED AT EACH STORAGE LOCATION

LOCATION	MILLION GALLONS STORED
Oakwood P.S.	167.5
Freud P.S.	749.8
Woodmere P.S.	236.0
Blue Hill P.S.	590.2
Conner Gravity	1077.0
Hubbell-Southfield	318.6
Baby Creek	2551.6
TOTAL	5690.7

storm wastewater captured by using the storage capacity already in the system amounted to 5.7 billion gallons. Assuming an average of 280 mg/l of suspended solids and 145 mg/l of BOD (32) entering the treatment plant during days on which rainfall occurred, DMWD was able to prevent 13 million pounds of suspended solids and 7 million pounds of BOD from pouring untreated into the Rouge and Detroit Rivers.

OPERATOR EVALUATION

The DMWD had been operating much of its potable water distribution system by remote control for several years prior to the advent of the remote control and date acquisition program for the wastewater collection system. In order to strengthen the continuity of a total systems control capability, it was decided to place the electrical hardware and its associated ductwork with the existing electrical control equipment for the water system. The combining of the two systems would reduce expenses and streamline the operation.

At the inception of the monitoring and remote control program the DMWD had as its system operators at least one operator experienced with the remote control of the water system and one operator transferred from the remote wastewater pump stations. The operators experienced in remote operation understood the importance of trends and the interdependence of the different segments of the system. This was a completely different concept from the fixed point, high wet well level alarm which was previously used. The operators experienced in the pump station operation aided the remote control system with their knowledge of station capabilities and the immediate impact of storm wastewater pumping. Together the operators supplemented each other's knowledge so that they were able to control the wastewater collection system independently.

Physical Layout of Control Center

Figure 72 shows the physical layout of the DMWD Systems Control Center. As the drawing indicates, the control panels are displayed along one-third of the perimeter of the control room. With the operators' desks situated near the focal point of the panel configuration, it is possible for each of the operators to watch both systems. The alarm printer is placed so that it is accessible to each operator and the operator's console is directly behind the operators. Next to the operator's console is a two-way field communications radio used to coordinate field operations. The data loggers are situated at a considerable distance from the operators. This was a result of the physical proximity to the computer and the desire to keep the control center uncluttered by numerous electrical ducts. Because the monitoring and remote control system is largely a data acquisition system, for most instances it was believed that this arrangement was sufficient.

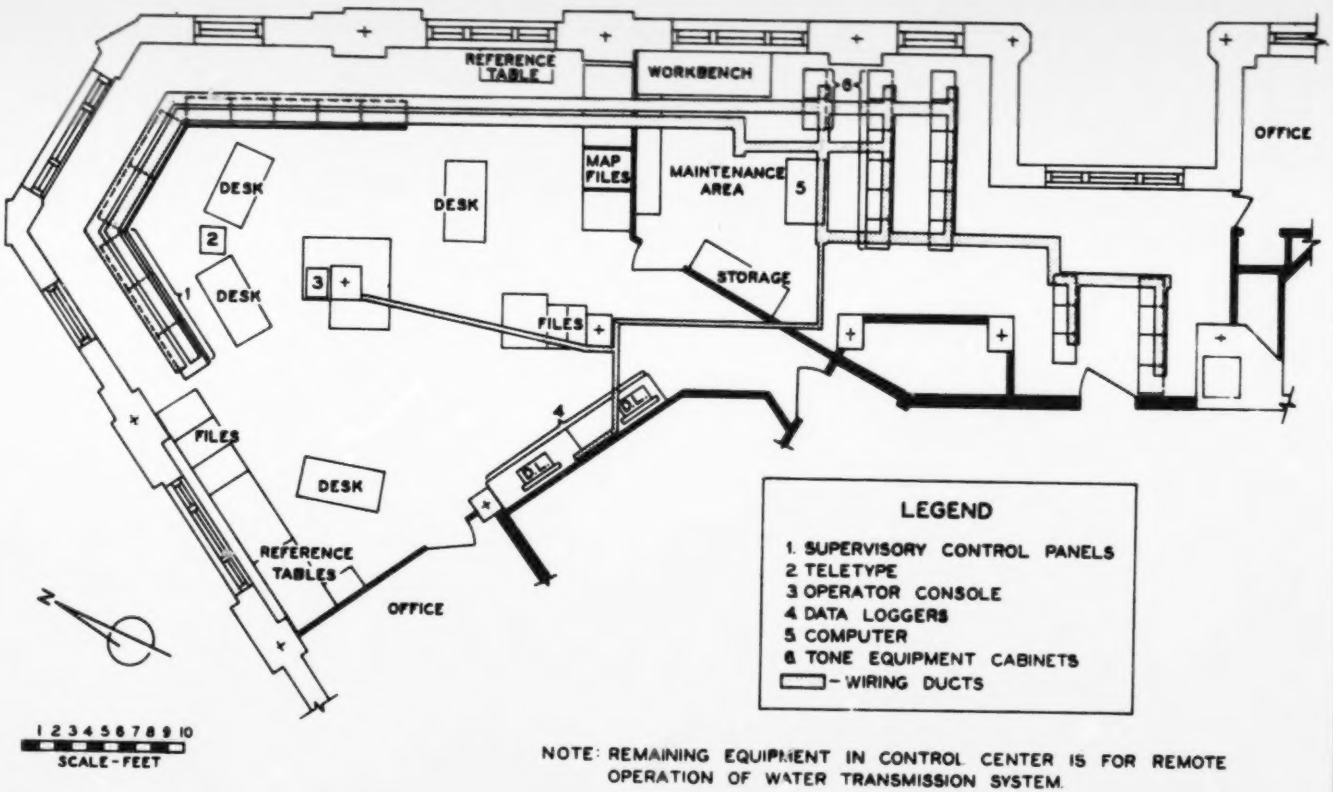
The control panels consist of the control switches for the pump stations and associated status lights and the strip chart trend recorders. Because the outside panels are at the visual limit of the operators, if the systems were to be expanded (expansion for both systems is expected) the operators will no longer be able to have full view of the whole system from one point. The result will be that one of the operators will be placed at some distance from the alarm printer and the operator's console.

The data loggers provide the hard copy of the rainfall and the level cell data. With the data logger being away from the operators, there has been less than full utilization of existing data. When storm events occur, the operators are not always able to spend the time away from the control panel needed to study the hard copy data. Thus, it happens that rainfall may subside or a rising water level in the sewer may crest long before the operators realize it.

Operational Effectiveness of Equipment

The DMWD has met with varying degrees of success with the equipment installed in the Systems Control Center. This is not to be construed as any endorsement or condemnation of any equipment manufacturer, but rather, an evaluation of DMWD's ability to utilize the equipment's capabilities.

As stated above, system control is a dual operation concerned with potable water distribution and wastewater collection system operation. The water distribution system is strictly a remote control facility centered around control of reservoir levels and set point modulation. The wastewater collection system operation uses remote control capabilities over sanitary and storm pumps, regulators and sluice gates. It also has extensive data acquisition capabilities which utilizes a small computer. The computer installation has limited storage and processing ability but is preprogrammed to activate a teletype printer under certain conditions. It is this last quality which has been most useful for operations.



NOTE: REMAINING EQUIPMENT IN CONTROL CENTER IS FOR REMOTE OPERATION OF WATER TRANSMISSION SYSTEM.

Figure 72- PLAN VIEW- SYSTEMS CONTROL CENTER

Present programming now calls for certain alarms to be displayed on the teletype. These alarms occur for such reasons as high or low wet well elevations at a pump station, high level readings in certain sewers, initial rainfall occurrences and communications failure. Previously, the possibility existed in which certain conditions could occur without the operator's full conscious knowledge of the event, such as the wet well of a sanitary pump station approaching a low level. This type of gradual change occurring over two or three hours can be easily overlooked. With the alarm system, this problem has been virtually eliminated from the control of the wastewater section. In comparison, detecting a gradual change in the potable water distribution system without the computer surveillance still can be a problem. Although the operators continue to keep a careful watch on the wastewater system, they are reassured that a vigilant backup system is present.

As it often happens, the advent of rain is synchronous with the advent of increased system control operator activity. With the simultaneous needs of two systems, the operators can be pressed for time. Hence the alarm system becomes increasingly valuable during storm events by reducing the pressure placed on the operators. This often gives the operators the time necessary to analyze incoming data and act in accordance with their function as a system control specialist.

The strip chart trend recorders are the next most successful item in system control. Designed as a continuous recording device, they indicate not only levels, but also the rate of change in level of a particular point. This has given the operators the ability to determine how fast conditions are changing in the system. If the operator observes a rise in the wet well elevation tapering off, he is inclined to withhold any storm pumping or storage reduction procedure for as long as possible, in the hope that it will prove unnecessary. If, on the other hand, the trend recorder indicates an extremely rapid rise in wet well elevation, the operator may initiate storm pumping procedures somewhat earlier than normal, rather than flood portions of the City.

In addition to the strip chart recorders which indicate rate of change in levels, the data logger is also programmed to display trend alarms on the teletype. However, when the trend alarms were programmed into the computer, there was little available data which could be used to set these alarm limits and the values selected were too high. Analysis of system response to major storm events has indicated that open channel gravity waves and pressure surges occur during intense storms. Although these waves can be detected at the wet wells by noting rapid level increases on the strip charts, the operators could use more lead time in order to effectively anticipate these waves. Upstream level data has given some lead time but in certain cases the operators have not detected these upstream trends. From the data which has been collected, it appears that a rate of rise in level of more than 0.5 feet per minute should be considered an alarm condition on the major sewers.

Some difficulty has been encountered with the sluice gate equipment and controls. The control switches for the sluice gates do not have a position indicator for any position other than fully open or fully closed. It often happens that the operators throttle down a sluice gate but do not fully close the gate. This information is not displayed on the panel, and it would have been useful to the operator if it had been displayed.

The operators have also experienced some difficulty with the long travel time of the sluice gates. Presently some of the gates have as much as a seven-minute travel time. If the operator wishes to operate the sluice gate at partial flow, he must watch and time the gate operation for three or four minutes. This is a continuous three or four minutes of the operator's time which is tied up each time one of these gates are activated. The DMWD does not believe that this much time should be devoted to one gate. Either sluice gates with shorter travel times or position indicators with supervisory computer positioning are required.

Dual System Operation

As previously stated, the Systems Control Center is a dual operation controlling both water and wastewater systems. Dual operation also has its associated good and bad characteristics. Because of the nature of potable water use, the water distribution system is constantly changing to meet varying demands. The operators are on a constant vigil watching the water system and are alert and responsive at all times. If the operators were to operate only the wastewater collection system, periods of dry weather would be quite boring indeed, for the system practically runs itself during dry weather. In addition, with rainfall occurring only 5 per cent of the time, using the same operators for the water system operation is good economics.

At the advent of storm events however, the simultaneous control of both the water distribution system and the wastewater collection system conflict with good operations. As rain threatens, the demand for potable water either drops or is expected to drop and, therefore, the pumping rates in the water system must be reduced. At the same time the operation of the wastewater collection system must be prepared to cope with expected and/or actual runoff. Under present procedures one of the operators controls the water system and the other operator controls the wastewater collection system.

Because of the telemetered rain data, the DMWD has also become the best source of information concerning instantaneous rainfall for the metro area. With 55 communities draining into the Detroit system, rainfall means a barrage of information requests. The information requests are handled by the operators as best they can, in addition to their primary task of controlling the water and wastewater systems. This arrangement does not, at times, leave much opportunity for the operators to examine incoming data displayed on the data loggers situated at some distance from the operators. Even though the operators do have some "leisure" time during dry weather, the operations required during rainfall events have the operators approaching their functional limit. This could be partially alleviated if the incoming data was in a more accessible position to the operators. It is believed that a maximum of information (within limits) should be presented before the operators without the expenditure of effort on the operator's part. It must be remembered that supplying the water needs of 3.5 million people while trying to capture a maximum amount of storm runoff can become somewhat difficult.

Traveling Operators

It is well known that any electrical or mechanical equipment can, at any given time, be counted on to malfunction. This simple fact of industrial prowess has caused the DMWD to introduce three separate, 24-hour-a-day, traveling operator crews. They inspect each water and wastewater pumping station daily and are on call for any system malfunction. Although maintaining these crews is expensive, it is an excellent safety factor which the DMWD feels its customers deserve.

CONNERS FLUSHING OPERATION

The visual inspection and sample analysis of the deposits in the Conner Gravity Sewer indicated that dry weather flow could be used to flush the sewer. The fact that the center barrel carried all dry weather flow and was relatively free of deposits further reinforced the flushing concept. For these reasons, remotely operated roller gates were installed at the transition section as shown in Figure 18. The electric operators and controls were discussed in detail in previous sections of this report.

Shortly after the flushing gate operation began, it was found that the deposits in the east barrel immediately downstream of the transition section were of sufficient depth to prevent flushing of this barrel without the wastewater topping the other two gates when they were in the lowered position. The mode of operation was then changed to concentrate flushing on the center and west barrels. The east flushing gate was left in the open position so that the turbulence created at the transition would undermine the deposits and thereby reduce their depth to allow flushing to be performed in this barrel. Figure 73 shows the deposits at the transition section along the easterly wall in the east barrel prior to installation of the flushing gates. This may be compared to Figure 74 which shows the effectiveness of this operation after about two years. The large sludge bank on the left of Figure 73 was reduced to a depth of about one foot. A channel about 1.5 feet deep has been cut through the deposits at the location behind the shovel shown in Figure 75. Note the outcropping of debris shown in Figure 75 to the right of the shovel handle. This same formation can be seen at the top of the sludge bank in Figure 74.

The west barrel, in which most of the flushing operation was concentrated, demonstrated that the concept of using dry weather flow to flush multiple

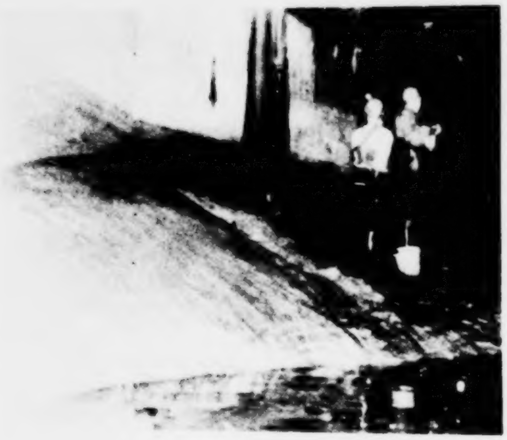


Figure 74 - E. BBL. AFTER FLUSHING

Figure 73 - E. BBL. SLUDGE BANK

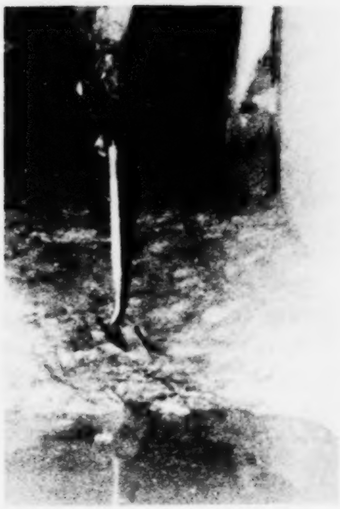


Figure 75 - E. BBL. BEFORE FLUSHING

Figure 76 - W. BBL. AFTER FLUSHING

barrel sewers was both practical and effective. The sludge deposits which were almost the same depth as those shown in the east barrel were reduced to a depth of about two feet. The material remaining was very coarse, consisting mostly of brickbats, gravel and concrete. It was quite difficult to walk on the material due to its coarseness. A sludge bank about five feet deep and 15 feet long extending about four feet out from the east wall of the barrel was the only remaining noticeable deposit. This can be seen in Figure 76.

As was mentioned previously, the limit switches on the motor operators were found to be slightly out of adjustment. This prevented the gates from closing fully and thereby reduced the effectiveness of the flushing operation. When the center and west gates were closed, the flow under these gates was such that the flow through the east barrel was not sufficient to flush the barrel effectively. At the time this condition was noted, about 5.5 feet of head was required to top the sludge deposits in the east barrel. The center and west barrels required only about two feet or less head and thus gate leakage was not a major problem when these barrels were flushed. For this reason, it is difficult to evaluate the east barrel flushing operation.

Any attempt to capture storm wastewater necessitates the installation of some type of retention facility with the inherent problem of sedimentation (11, 12). In these retention basins, the sludge deposits must be removed by either manual cleaning or by some system of backflushing. Both of these cleaning methods result in high operating costs. The successful flushing of the Conner Gravity Sewer has proved that dry weather flow can be used to remove sludge deposits. It has also indicated that in-system storage of storm wastewater and the flushing of the sewer following storage is both economical and practical. However, it has been DMWD's experience that large, heavy debris does enter the sewer system and provisions for periodic manual removal of such items should be provided.

Based on the experience gained, it appears that in-system storage and on-line retention facilities are the most desirable methods of capturing storm wastewater. In a combined sewer system similar to the Detroit system, where many of the sewers are on relatively flat grades, it may be possible to add additional barrels next to existing barrels in conjunction with upstream control devices in order to implement storage. Using concepts similar to the Conner flushing operation, it would be possible to store large volumes of storm wastewater and to flush these sewers following dewatering. In addition, existing relief sewers could be modified to provide for storage during small storms and allow for flushing if controlled connections were provided. Multiple, large volume connections between major sewers could also be constructed to provide additional retention. In both of the methods, dry weather flow could be routed to provide for flushing.

SURVELLIANCE

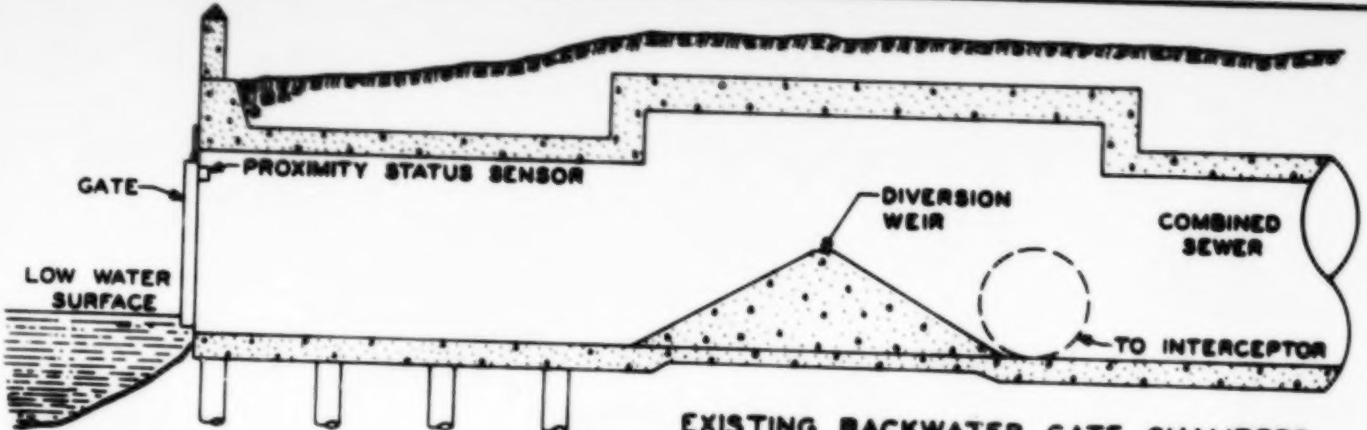
The 24-hour surveillance characteristics of the monitoring and remote control program have been particularly valuable. This feature has emerged as a "second maintenance crew." If a backwater gate does not close after a rainstorm, a maintenance crew is immediately dispatched, possibly days before the regular maintenance program would have caught the backwater gate malfunction. Regulator malfunctions also have been discovered in a similar fashion.

One of the surprises resulting from the surveillance aspect occurred through unusual circumstances. As often happens in the Detroit area, a rainfall of an inch or more occurs during the winter when the ground is frozen and covered with ice. As expected, the runoff under these conditions is very high. During one of these storms, the system overflowed into the Rouge River at most of the available relief locations. However, despite extremely high sewer levels, three of the backwater gates did not open. Upon investigation, it has found that approximately 12-inches of ice had formed on the Rouge River in such a manner that the backwater gates could not possible open. Although overflowing into the Rouge River is not desirable, neither is flooding portions of the city. A number of the backwater gates along the Rouge River were subsequently redesigned -- solely because of information gained from the monitoring and remote control system. This design change is shown in Figure 77. As can be seen, the backwater gates are being located atop the diversion dams. During the winter months, the river level will be below the crest of the dam and ice formation will not hinder gate openings.

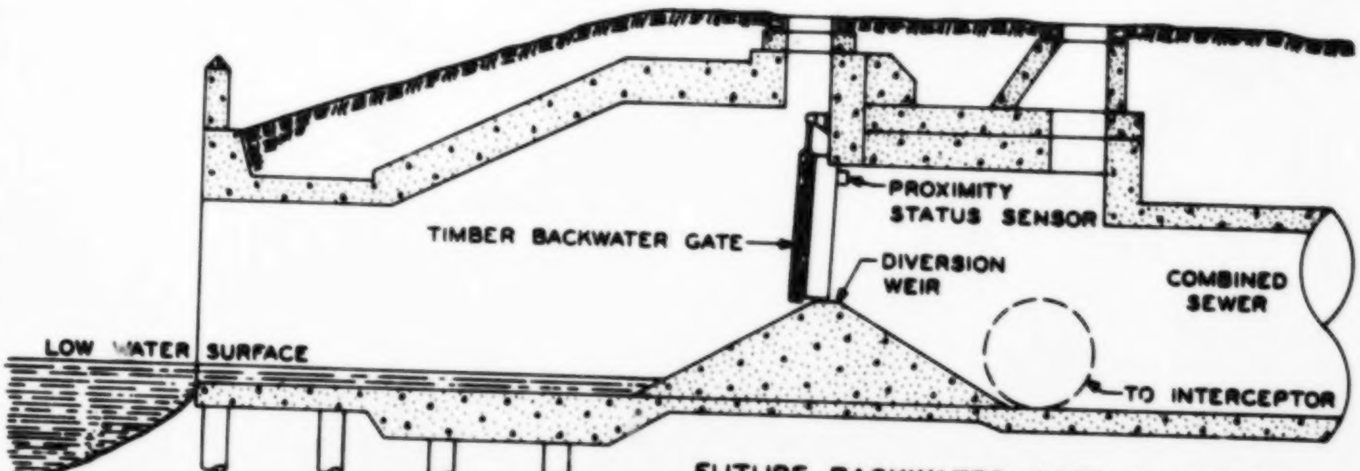
DEWATERING

The DMWD also relies heavily on the monitoring and remote control program in dewatering operations. As previously mentioned, many of the suburbs whose sanitary sewage empties into the DMWD system have constructed storm water retention basins as a method of preventing overflows from their drainage districts. After storm events, it is necessary to dewater these basins into the Detroit System. By using the information provided by the monitoring and remote control programs, Systems Control Center can determine the capacity available in the various sewers. The Systems Control Center operators have thus been able to modulate the amount of stored runoff entering the system from the suburban retention basins so as to create the least detrimental effects within the system. Without the level sensors, this was impossible to accomplish, and stored runoff entered the system on an "as available" basis. Thus the dangers of having a system running at full capacity should rainfall once again occur during the dewatering procedure have been reduced.

The suburban communities have been most cooperative in coordination of their dewatering activities with the Systems Control Center. However, this has placed an additional burden on the Systems Control Center



EXISTING BACKWATER GATE CHAMBERS



FUTURE BACKWATER GATE CHAMBERS

Figure 77-DESIGN CHANGE IN BACKWATER GATE CHAMBERS

operators since all coordination must be done by telephone. In addition to the requests for rainfall data, the operators must also furnish information relative to available system capacity and suburban dewatering priorities.

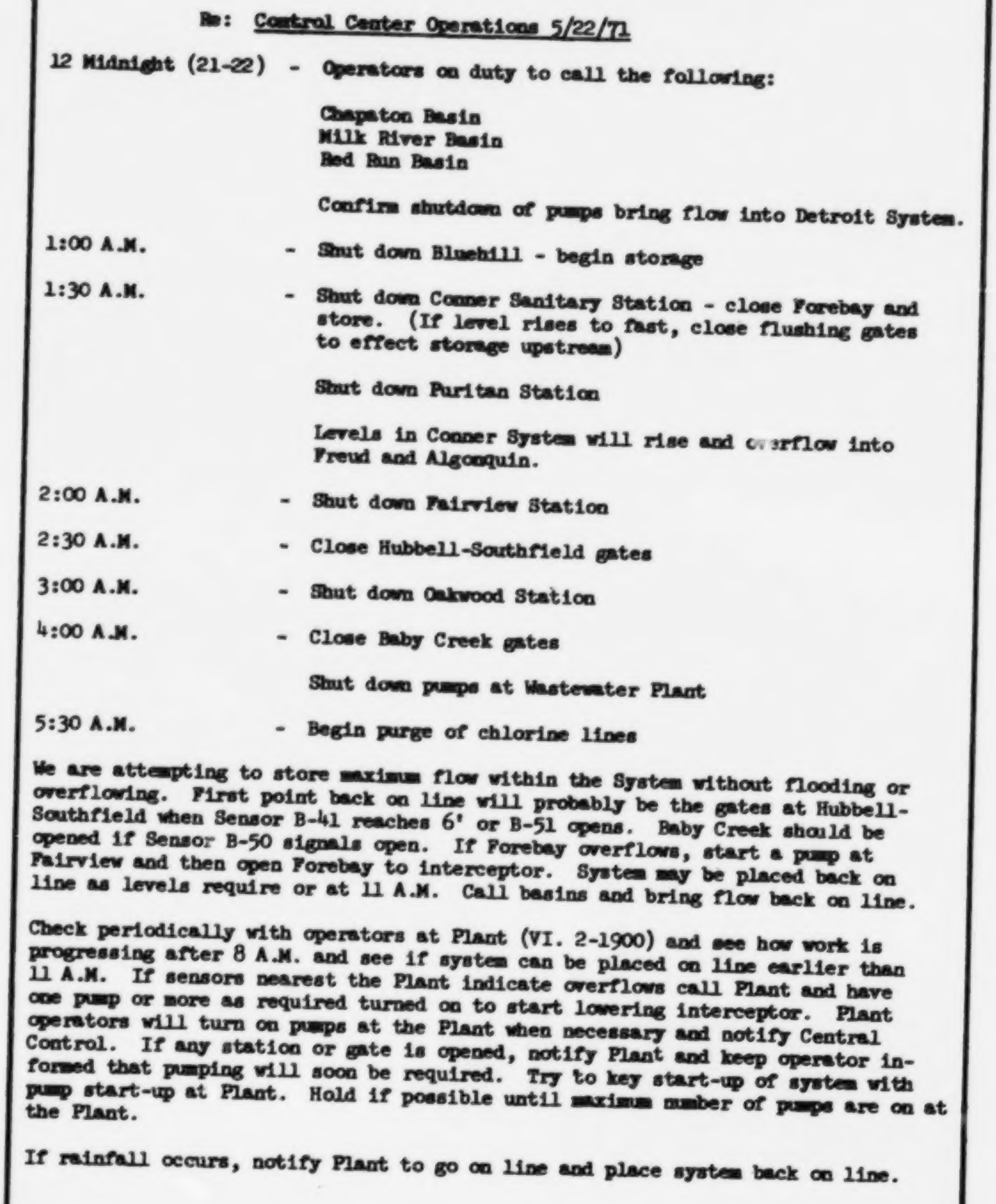
Several modifications to the Systems Control Center could be made which would significantly improve dewatering operations while at the same time alleviating some operational difficulties. One of these would be to graphically display the major retention basins and those sewers which service each basin along with the basin and sewer levels. The graphic display would enable operators to visualize both basin and downstreams levels and to use this information to establish dewatering priorities based on the needs of each suburb.

Another modification would be to monitor levels upstream of suburban connections to the Detroit system. It has been found that spot storms have occurred in particular suburban districts while bypassing the majority of the service area. If the storm bypassed existing rain gages, the only indication of the occurrence of the storm to the operators at the Systems Control Center was rising levels in the upper reaches of the sewers within the City of Detroit. If operators had advance warning of these storm events by monitoring levels in various suburban systems, they could better prepare the Detroit system to receive this additional flow. In addition, several of the metered suburban connections are adjustable. They are set for contracted flow amounts and are designed to shut off flow into the Detroit system when levels in the Detroit system rise above certain fixed points. If, in addition to monitoring levels upstream of the connections, the Systems Control Center is given the capability to override the automatic on-site controls, it will be possible to accept additional flow through these connections during spot storms.

A third modification would be to provide data links from the data acquisition system to the suburban communities. Instead of calling the Systems Control Center operators for rainfall data, available system capacity and dewatering priorities, this information could be sent directly by the computer. Data transmission could be blocked so that each community would receive only that information which is pertinent to its system.

SYSTEM SHUTDOWN

Figure 78 is a copy of the actual system shutdown procedure used to facilitate construction at the Wastewater Treatment Plant. The first stoppage of flow is initiated at the suburban communities which have storage capability and are tributary to the DMWD treatment plant. This is done at midnight at the locations furthest from the plant. Starting at 1:00 AM. DMWD starts to store in the upper reaches of its own system beginning at the Bluehill pump station. The Puritan and Conner pump stations are the next facilities to be taken off line. Notice that once the 53 million gallons of storage at the Conner System is filled the



Re: Control Center Operations 5/22/71

12 Midnight (21-22) - Operators on duty to call the following:

Chapaton Basin
Milk River Basin
Red Run Basin

Confirm shutdown of pumps bring flow into Detroit System.

1:00 A.M. - Shut down Bluehill - begin storage

1:30 A.M. - Shut down Conner Sanitary Station - close Forebay and store. (If level rises to fast, close flushing gates to effect storage upstream)

Shut down Puritan Station

Levels in Conner System will rise and overflow into Freud and Algonquin.

2:00 A.M. - Shut down Fairview Station

2:30 A.M. - Close Hubbell-Southfield gates

3:00 A.M. - Shut down Oakwood Station

4:00 A.M. - Close Baby Creek gates

Shut down pumps at Wastewater Plant

5:30 A.M. - Begin purge of chlorine lines

We are attempting to store maximum flow within the System without flooding or overflowing. First point back on line will probably be the gates at Hubbell-Southfield when Sensor B-41 reaches 6' or B-51 opens. Baby Creek should be opened if Sensor B-50 signals open. If Forebay overflows, start a pump at Fairview and then open Forebay to interceptor. System may be placed back on line as levels require or at 11 A.M. Call basins and bring flow back on line.

Check periodically with operators at Plant (VI. 2-1900) and see how work is progressing after 8 A.M. and see if system can be placed on line earlier than 11 A.M. If sensors nearest the Plant indicate overflows call Plant and have one pump or more as required turned on to start lowering interceptor. Plant operators will turn on pumps at the Plant when necessary and notify Central Control. If any station or gate is opened, notify Plant and keep operator informed that pumping will soon be required. Try to key start-up of system with pump start-up at Plant. Hold if possible until maximum number of pumps are on at the Plant.

If rainfall occurs, notify Plant to go on line and place system back on line.

Figure 78 - CONTROL CENTER OPERATIONS 5-22-71

flow is routed to the 20 million gallon Frued system. From 2:00 AM to 4:00 AM, additional control points are closed and pump stations shut down until the pumps at the treatment plant can be taken off line. Because the work to be done is on equipment near the end of the treatment process, 1-1/2 hours is given for the wastewater to flow through the plant before construction begins.

The primary factor involved in the sequencing of the facilities shut down is the time lag from the facility to the treatment plant. By shutting down a control point after most of the flow from the preceding upstream control point has passed, the system will be able to store a maximum volume. The information following the shutdown procedure suggests action to be taken by the operators for certain anticipated developments. It has been found that the lowest flow occurs early Sunday morning. When system shutdown coincides with the Sunday morning flow period, it has been possible to create a no-flow condition at the wastewater plant for up to six hours. During this time all flow is stored internal to the system and no overflows occurred.

The DMWD also employs the system shutdown techniques in order to inspect certain sewers. The letter in Figure 79 illustrates the procedure used in conjunction with the inspection of the Oakwood Interceptor. By referring to Figure 79 it can be seen that storage is being implemented in the eastern portion of the city while the western portion of the city, which is serviced by the Oakwood Interceptor, is being drawn down. This differs from the first pumpdown procedure shown in which the system was uniformly drawn down. The uniform drawdown procedure was used to allow the treatment plant to go off line for as along as possible without concern about high sewer levels upstream, whereas the second procedure was intended to keep the interceptor level as low as possible but for only a short period of time. Because the portion of the interceptor to be inspected is directly upstream of the treatment plant and because there are no screening devices between the inspection site and the pump intake, it was necessary to take the pumps off-line before the inspection team could enter the sewer. For this reason, the wet well elevation had to be lowered as much as possible as referenced in the Figure 79. Once the inspection team entered the interceptor the system was completely shut down and system control was limited solely to a monitoring function.

The preceding examples of system shutdown illustrate how the treatment plant may be shut down for short periods without causing overflows. The first example illustrated a total system pumpdown, while the second example illustrated a partial pumpdown of the western part of the system. Other sewer inspections have been made by following similar shutdown procedures. The major difference is that the pumps at the Wastewater Plant are not taken off line. As an example, the Fairview Interceptor Lift Station was taken off line for over eight hours while an inspection was made of the 9-foot diameter discharge conduit. The monitoring and remote control capability has provided additional safety to individuals making these inspections while at the same time providing a continuous check on overflow status to insure that sanitary wastewater overflows do not occur.

Re: Sunday Inspection of Oakwood Interceptor
Control Center Operations-Feb. 20, 1972

The following outline will govern the operations at the System Control Center and Wastewater Plant Pumping Station on Sunday, February 20, 1972. These steps are necessary to permit the physical inspection of the Oakwood Interceptor from Carbon Avenue into the Wastewater Plant site.

Operators on duty to call the following stations and confirm shutdown of pumps bringing flow into Detroit:

3:00 A.M.
- Chapaton Basin
- Milk River Basin
- Red Run Basin
- Call Wastewater Plant to start system pumpdown
- Shut down Bluehill -- begin storage

4:00 A.M.
- Shut down Conner Sanitary Station
- Close Conner Forebay Regulator gates (If additional storage is required, lower all flushing gates and store upstream.)
- Shut down Puritan

NOTE: Levels in Conner System will rise and overflow into the Freud pumped system.

- Check Wastewater Plant -- request additional pumps if wet well is above elevation 72.0.

4:30 A.M.
- Shut down Fairview
- Check with Wastewater Plant -- 1 Hr. to shutdown
  Request additional pumps if wet well is above elevation 71.0.

5:00 A.M.
- Close Hubbell-Southfield gates -- begin storage. Open gates at first overflow indication (B-51) just enough to contain flow within the system.
- Call Dearborn -- confirm shutdown

5:30 A.M.
- Close Baby Creek gates

5:30 to
6:00 A.M.
- Shut down pumps at Wastewater Plant when call is received from System Control. Wet well to be at Elevation 69.0. Restart pumps only after call is received from System Control.

6:00 A.M.
- Inspection team will enter the interceptor at Carbon Avenue and exit at the Plant after checking the area where the PC-215 tunnel crosses under interceptor.
- After all-clear is received from inspection team, start up system. Call suburbs to end storage. (All suburban areas have been requested to hold a minimum of four hours.)

In the event of rain, inspection shall be cancelled and rescheduled for Sunday, February 26, 1972. Call all suburbs in case of cancellation.

Figure 79 -CONTROL CENTER OPERATIONS 2-20-72

SECTION X

DATA UTILIZATION

DATA REDUCTION

As a result of the Monitoring and Remote Control Project, a voluminous amount of data was collected. As previously discussed, the data output is of hard copy form and the data sheets measuring 28-inches by 22-inches with up to 70 different items of data per line. For a one-month period, approximately 75 data sheets of sewer levels, rainfall and overflow information is generated. The data on sewer levels was to be used for the engineering purposes of studying the effects of rainfall on certain sewer levels and determining the amount which the system is utilized. It was believed that the information would not be of significant value to anyone not directly involved in the project. However, both the rainfall data and the overflow data could be of interest to various individuals. Because the raw data is difficult to understand and reproduce, the data was first reduced by hand into an acceptable form and them processed by an off-line computer for further refinement. The results of one month's data constitutes Appendix B of this report.

The first section of the monthly report consists of the data on combined sewer overflows. Page one is a graphic summary for the month showing the days on which overflows occurred, the daily and monthly overflow totals, the total number of times an overflow occurred at a specific point, the number of storm wastewater pumpages and the Equivalent Uniform Depth of rainfall if any occurred for a particular day. The rest of the overflow report is an expanded listing of the date, the number of overflows for the day, type of sensor at the point of overflow, sewer location and size, the duration of overflow at each location and additional pertinent remarks concerning overflow information. On the last page of the overflow section appears a brief summary for the month and a listing of any sensor which was not in operation for any time during the month.

The second section of the monthly report is a display of the reduced data gathered from the telemetered rain gages. The amount of rainfall at each gage along with the produce of the rainfall amount times the Thiessen Polygon weighing factor is listed for each day of the month. The summation is listed and the area used in the E.U.D. computations. On certain occasions, a particular gage may be experiencing communication difficulties and the data is therefore not used in the E.U.D. computations. It may also be desirable to limit attention to just one or two rain gate locations in order to study spot rain cells. The last page lists the rain gage location and the corresponding area of the Thiessen Polygon in square miles.

It is believed that the monthly report supplies a sufficient amount of information to interested individuals without being too overburdened with details. As it was, there were approximately 220 pages generated in preparing the monthly report for the 18 months of study. This was, however, an improvement over the approximately 1400 pages of the oversized output. It is hoped that the single representative monthly report supplied in Appendix B will adequately convey the information output. The raw data is available for those interested in utilizing it for model studies or other applications.

OVERFLOW INFORMATION

Although the monthly synopsis is useful in obtaining an overall view of the system performance, engineering analysis demands a much closer examination of the many pages of hard copy data. From this data total rainfall, storm intensities, runoff rates, total runoff, sewer hydrographs and overflow duration can be calculated; points of needed relief and the amount of sewer utilization can be determined. All of this information is of significant importance when planning which methods of reducing combined sewer overflows lend themselves to a particular wastewater collection system.

Table 8 is a list of the various overflow points from the wastewater collection system into the Detroit and Rouge Rivers. From the hard copy data sheets, the duration of each overflow was determined for each rainstorm. The overflow durations for each point were summed and divided by the duration of the study period to obtain the percentage of the time for which overflows occurred.

Note that the Detroit system as a whole overflowed an average of 1.29% of the time or 112.8 hours per year per outfall. This figure is a direct average of the numbers found in the right-hand column labeled "% time overflow". Some of the overflow points were never used while others seemed to overflow at the slightest amount of rainfall. Although there could be no direct computation as to the volume of storm wastewater discharged at the various outfalls, the information does indicate which portions of the wastewater collection system are in the greatest need of overflow abatement measures.

These overflow computations will allow the DMWD to plan future construction projects which will alleviate those sewers which present the greatest overflow problem. These decisions would be based on the sewer size, the duration of overflow and sampling.

UTILIZATION OF EXISTING FACILITIES

As indicated, the most chronic overflow point is at the Conant-Mt. Elliott regulator. Because the sewer is large, 16'-3" ID, and possesses a corresponding flow volume, it is believed that a control facility operated from the system control center would result in a substantial reduction in overflows and therefore be of significant value.

TABLE 8
SUMMATION OF OVERFLOW DATA

SEN.	TYPE SEN.	SEWER DESIGNATION	NO. BBLS.	SEWER SIZE	% TIME OVERFLOW
B-01	P	FOX CREEK	1	15-6 X 18-0	0.00
B-02		NOT USED			
B-03	P	CONNER GRAVITY	2	17-6 X 22-11	0.16
B-04		NOT USED			
B-05	E	MC CLELLAN-CADILLAC	1	6-3	1.40
B-06	P	FISCHER	3	10-6 X 11-6	4.29
B-07	E	IROQUOIS-V DK-CRANE	3	6-0	0.34
B-08	E	HELEN PLUS FOUR	1	9-0	2.54
B-09	E	MT ELLIOTT (MELDRUM)	4	5-0	6.12
B-10	E	CONANT-MT.ELT.(LEIB)	2	11-0	7.66
B-11	P	ADAIR	1	5-0	2.70
B-12	P	JOS CAMPAU	3	6-8 X 8-8	0.00
B-13	E	CHENE	1	4-0 X 5-3	1.15
B-14	E	DUBOIS	3	5-0	1.08
B-15	E	ST. AUBIN	1	3-6 X 4-8	0.21
B16A	E	ORLEANS	1	3-0	0.00
B16B	E	ORLEANS RELIEF	1	5-0 X 7-0	0.25
B-17	E	RIOPELLE	2	3-6	0.44
B-18	P	RIVARD	1	5-3 X 6-0	0.51
B-19	E	HASTINGS	1	4-0 X 3-6	0.46
B-20	P	RANDOLPH	1	8-0 X 5-0	0.18
B-21	P	BATES(BRUSH)	3	8-6 X 6-4	4.69
B-22	E	WOODWARD	1	8-0 / 9-0	1.83
B-23	P	GRISWOLD	2	7-0	4.00
B-24	P	FIRST-HAMILTON	2	10-0 X 10-6	2.73
B-25	E	CABACIER	1	4-8 X 3-8	0.37
B-26	E	ELEVENTH ST.	2	5-0	0.22
B-27	E	TWELFTH ST.	1	5-2	0.28
B-28	E	VERMONT	2	4-3	0.45
B-29	E	EIGHTEENTH	1	7-0	0.00
B-30	P	TWENTYFIRST	1	4-6 X 6-0	0.02
B-31	E	TWENTHFOURTH	1	8-0	0.91
B-32	P	WEST GRAND BLVD.	1	3-0	0.01
B-33	E	SWAIN	1	3-0	0.01
B-34	E	SCOTTEN	2	4-8	2.25
B-35	E	MC KINSTRY	2	4-6	0.15
B-36	P	CLARK	3	8-8 X 7-6	1.38
B-37	E	FERDINAND	2	4-6	1.40
B-38	P	MORRELL	1	9-0	0.91
B-39	P	JUNCTION(CALVARY)	1	13-0	1.76
B-40	P	CAMPBELL-MILT-JUNC	3	6-6	0.66

TABLE 8 (Cont.)
SUMMATION OF OVERFLOW DATA

SEN.	TYPE SEN.	SEWER DESIGNATION	NO. BBLS.	SEWER SIZE	% TIME OVERFLOW
B-41	E	DRAGOON(LIVERNOIS)	1	9-3 X 10-6	0.01
B-42	E	SCHROEDER-WATERMAN	1	6-0 / 6-10	0.00
B-43	E	SOLVAY	1	2-0	1.39
B-44	E	CARY	1	3-4 X 5-3	0.46
B-45	P	DEARBORN(SLOAN)	1	5-9	0.00
B-46	P	PULASKI-PORTLAND	1	5-0 / 6-6	0.00
B-47		NOT USED			
B-48	P	CARBON	1	3-4 X 5-0	0.43
B-49	P	FLORA	1	3-4 X 5-3	0.06
B-50	P	BABY CREEK	2	14-6 X 17-6	1.97
B-51	P	HUBBELL-SOUTHFIELD	2	14-6 X 12-0	1.37
B-52	P	WARREN	1	7-6	1.24
B-53	P	TIREMAN-JOY	1	13-9	0.82
B-54	P	W.CHICAGO-PLYMOUTH	1	14-0	0.09
B-55	E	W.CHI(W OF ROUGE)	1	4-6	4.48
B-56	E	PLYMOUTH(W OF ROUGE)	1	4-0	0.70
B-57	P	GLENDALE(S'CFT REL)	1	13-0	0.59
B-58	P	DOLSON(SCHOOLCRAFT)	1	10-6	0.06
B-59	E	WEST PARKWAY	1	6-6	0.00
B-60	E	SCHOOLCRAFT(WEST)	1	4-6	0.00
B-61	E	LYNDON	1	12-0	5.08
B-62	E	FENKELL	1	2-0	0.51
B-63	P	PURITAN STATION	1	10-3	5.70
B-64	E	PURITAN(E OF ROUGE)	1	8-0	1.78
B-65	P	MC NICHOLS	1	14-0 X 14-0	1.57
B-66	P	GLENHURST	1	1-9 / 1-0	0.15
B-67	E	7 MILE(W OF ROUGE)	1	9-3	1.25
B-68	E	7 MILE(E OF ROUGE)	1	8-6	0.00
B-69	E	FRISBEE	1	8-3	1.74
B-70	E	PEMBROKE	1	13-0	1.69
B-71		NOT USED			

NOTE:

1. P = Proximity Sensor @ Backwater Gate
2. E = Electrode Probe @ Weir
3. Average % Time Overflow of System = 1.29

Another possibility based on the overflow data is revealed from an examination of level sensor 41 on the Livernois Relief Sewer. The Livernois Relief Sewer (Figure 80) was constructed in 1950 as a storm relief for the upper portion of the Baby Creek district. Flow into this sewer was designed to enter through high level, porthole connections from the 17'-9" x 13'-5" Wetherby arch. The sewer is 10'-6" in diameter and has a length of 21,879 feet with a grade of only 0.05% for most of its length. Built as a relief, it is below most sewers that it crosses and has very few interconnections with any of the other sewers in the area. Overflow data indicated that the Livernois Relief Sewer overflowed only 0.01% of the time -- far below the average for the system as a whole. Before the monitoring and remote control program, it was not known how often or to what extent the relief sewer was used. With the data obtained, it was found that there was seldom any storm flow in the sewer. Because of its relative depth, its flat grade, its length and the few interconnections with other parts of the wastewater collection system, it is believed that the Livernois Relief Sewer could serve as a very successful retention facility. If the present high level connections to the Wetherby sewer were modified to a remotely controlled, low level connection, the ability to route both storm and dry weather flow to the sewer would be present. Thus the DMWD would be able to route storm wastewater flow into the relief sewer for storage and route dry weather flow to the sewer in order to flush out sedimentation which occurred as a result of the storage. Not only can this redesign add additional storage and flow routing capability at the Livernois Relief Sewer, but any relief sewer with high level connections can be altered by the basic design of Figure 81 to add storage and flow routing to many locations in the City. Other similar locations are presently being investigated.

POSSIBLE ADDITIONS TO EXISTING SYSTEM

In Section IV, In-System Storage, it was mentioned that the storage in the Hubbell-Southfield Sewer is limited by the depth of water at the backwater gate. Normal river level at the backwater gate is approximately 1.5 feet as shown on Figure 82. Although the Hubbell-Southfield Sewer is a 14'-6" x 12' double box, the amount of storage is only 3.5 million gallons before the 1.5 feet head at the backwater gate permits an overflow to occur. However, as also previously discussed, during periods of heavy runoff the Rouge River has risen to a level which exerts 8 feet to 10 feet of head at the Hubbell-Southfield backwater gate. Under these conditions an estimated 23 million gallons of storage is available in the sewer.

From the data collected under the monitoring and remote control program, it has been found that the Hubbell-Southfield Sewer overflowed 1.37% of the time (Table 8). It has also been found from the level sensor data that during the high runoff conditions when appreciable amounts of storage have taken place, there have been no adverse effects upstream. With this information it is evident that significant storage could be

NOTE:

UTILIZATION OF THE LIVERNOIS RELIEF SEWER WOULD RESULT IN APPROXIMATELY 8,000,000 GALS. OF STORAGE

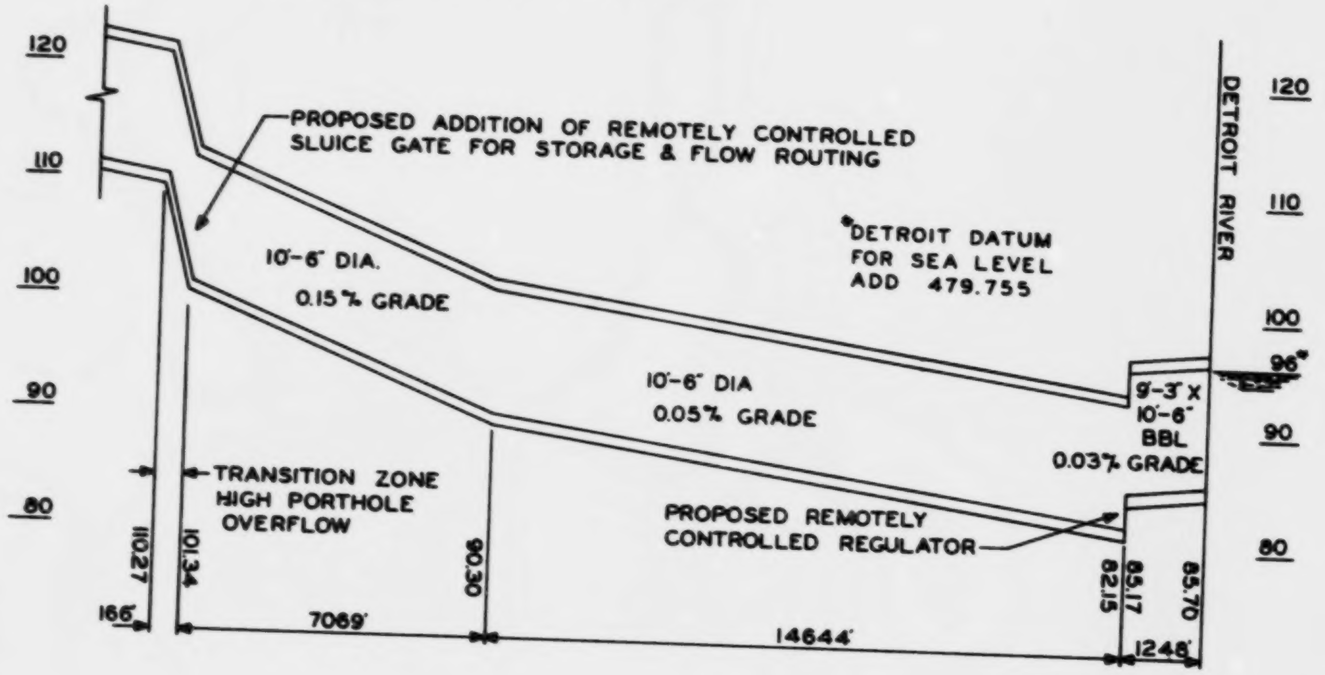


Figure 80-POSSIBLE LIVERNOIS RELIEF MODIFICATIONS TO IMPLEMENT STORAGE

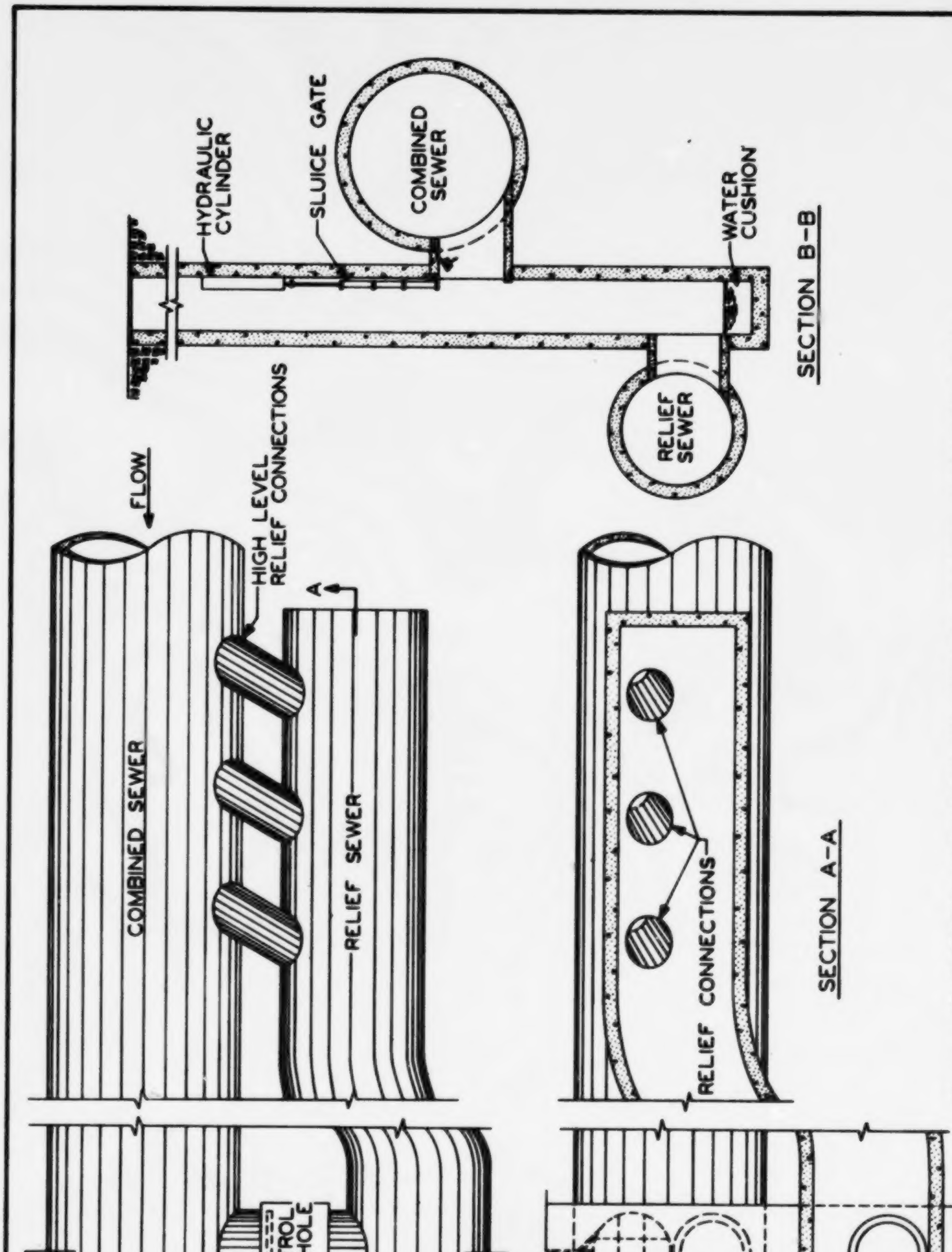


Figure 81-DESIGN CHANGE IN RELIEF-SEWER CONNECTIONS

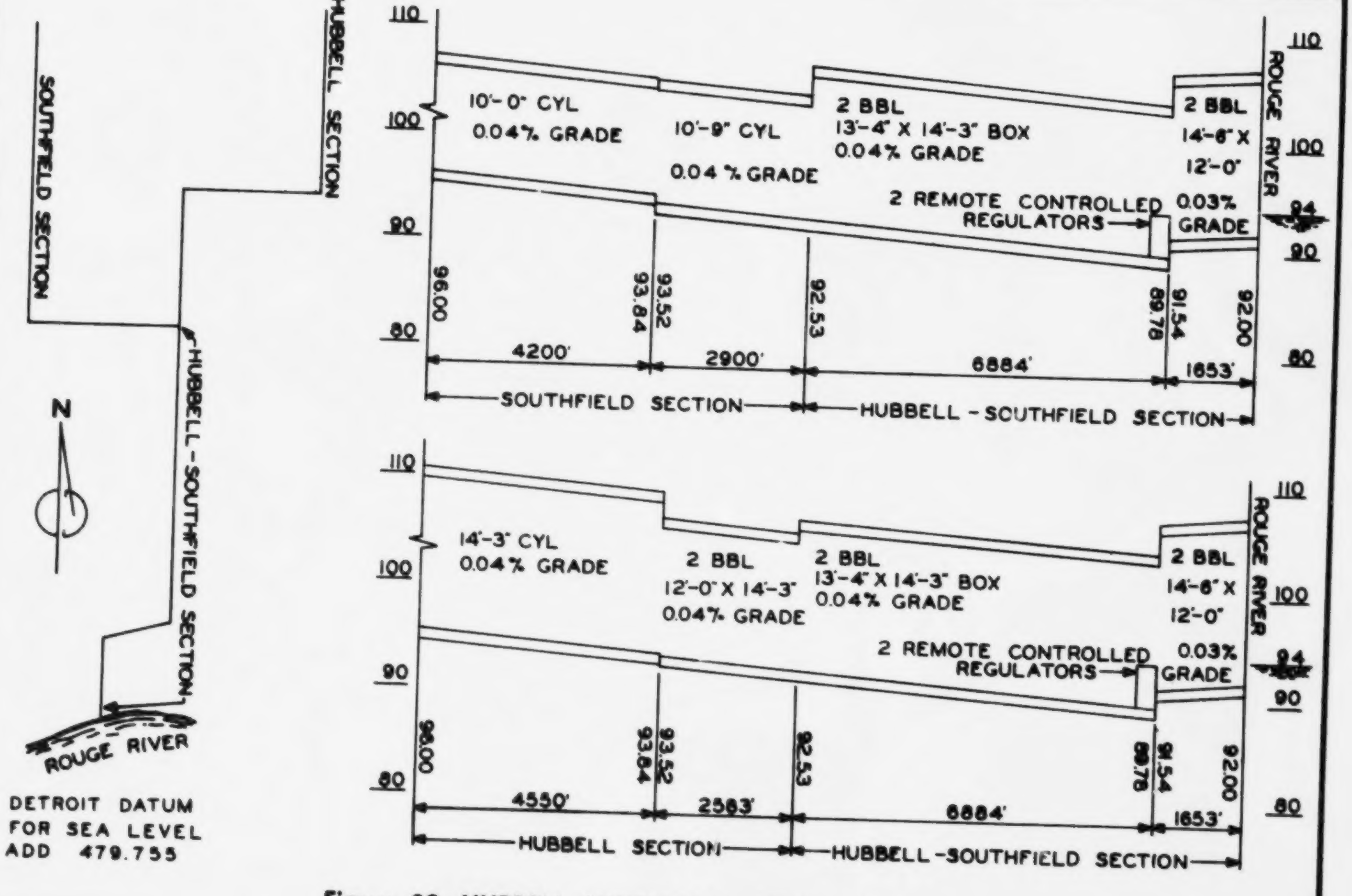


Figure 82 -HUBBELL-SOUTHFIELD SEWER SYSTEM

achieved in this sewer during the low river levels at the backwater gate. The additional 20 million gallons of storage could be used to capture storm wastewater from the less severe rainfalls.

The largest amount of storage could be achieved if some type of level control device was placed at the outfall. This would also provide a maximum amount of flow control, since the regulator just upstream of the outfall is already remotely controlled. However, it must be remembered that overflows are of an emergency nature and if storage is to be controlled at the outfall, it must be done by a "fail-safe" method. One such method which displays promise is the inflatable rubber dam. This dam can be designed so that the dam height is controlled from the Systems Control Center to regulate storage. In addition, the dam can be provided with independent control routines to insure overflow capability should power or communications be interrupted or should high storage levels be ignored by the control operators. This will provide the necessary form of emergency backup along with providing controlled storage. Having the ability to implement storage where previously an overflow would have occurred should cut the overflow time well below the present 1.37% and capture an additional 20 million gallons of storm wastewater. Presently this type of installation is being considered to further augment the existing monitoring and remote control program.

POSSIBLE ADDITIONAL INFORMATION DEVICE

Ocassionally, rain cells develop in the area which do not follow the usual west-to-east weather pattern. These storms either come across Canada from the south moving in a northerly direction or from the northeast moving in a southerly direction. These conditions were not adequately foreseen when deploying the telemetering rain gages and therefore no gages were placed in the area north of Detroit or in Canada to the south. When these conditions occur, little, if any, warning is received by Systems Control Center. In many instances these storm cells have been unusually severe. One recent storm dropped nearly three inches of rain in a one-hour period as recorded on one of the weighing type gages, and sections of the City were flooded as a result. At times the first indication of these rain cells at Systems Control Center has been rapidly rising sewer levels. In these instances, it is impossible to prepare the system to receive additional flow using the storm anticipation techniques that have been developed.

It also happens that rain cells following the normal weather pattern skirt the outlying telemetered rain gages and, although rain does not fall on the City of Detroit, heavy rains occur in the suburbs tributary to the Detroit system. This condition has also added large volumes of storm wastewater to the system without any indication of rain recieved at Systems Control Center.

The storm anticipation technique employed by Detroit can only be effective if sufficient information is received by the system operators. Although great quantities of information have been gathered through the monitoring aspect of the program, it has been found that in some areas the information is insufficient. Rainfall data collection can be, at times, the area in which the most apparent lack of information occurs.

In Detroit, as in most portions of the country, the U.S. Weather Bureau uses radar technology to yield information on current rainfall status in the area. Information such as the intensity of the storm, direction of travel and the form of precipitation (either rain or snow) is known. The Weather Bureau has recently made this information available in a form which can be of great promise to the capture of storm wastewater. Specifically, it is now possible to receive the information from the Weather Bureau's radar scope by remote readout. Thus the system control operators would have access to two independent sources of rainfall information. The telemetering rain gages can give intensities and totals for specific points and the radar readout would yield the area of rainfall, direction and speed of travel and the intensity of the storm for an area with a radius of 125 miles around Detroit. This data should give the Systems Control Center operators enough information to negate the possibility of being caught unaware of impending rain. Therefore serious consideration is being given to the inclusion of the remote readout from the U.S. Weather Bureau to the DMWD system.

ALTERNATIVES TO IN-SYSTEM STORAGE

The research effort into the various methods to reduce pollution from combined sewer overflows appears to have taken several courses (33). These alternatives may be divided into five major groups: sewer separation, combined sewer overflow treatment, surface drainage area control, off-line storage and in-system storage. Each of the methods has certain advantages and disadvantages and will be discussed briefly for comparison purposes.

Sewer Separation

Total sewer separation on a national scale has been estimated to cost over seventy billion dollars (34). In Detroit it is estimated that it would take 30-40 years to design and construct a completely separated system at a cost of over two billion dollars (35). In addition, the effectiveness of sewer separation in reducing pollution of our waterways has been seriously questioned (3, 5, 36-38). It is evident that urban runoff contains high amounts of solids, fertilizers, pesticide residues, oil and organic pollutants from animal droppings, leaves, litter and grass clippings, and even separation of the sewer system would not eliminate the pollutional problem of urban runoff (39-42).

Combined Sewer Overflow Treatment

Biological, physical and chemical treatment of combined sewer overflows have been investigated (33, 43-49). All of these methods have limitations which make them unacceptable for use at a majority of the Detroit outfalls. Very few of the 76 overflow points in the Detroit system are designed for less than 100 cfs relief with many approaching 1000 cfs and the largest being 12,400 cfs. In addition, most of the outfalls are located within the existing street rights-of-way and are bordered by either private residences or industry. Thus, the amount of land required for the installation of treatment devices is limited, and large amounts of additional land would have to be purchased before any such method could be integrated into the system. Therefore, if on-the-site treatment is not a suitable solution, other methods designed to eliminate the pollutional effects of combined sewer overflows must be examined.

Surface Drainage Area Control

The concept of surface drainage area control is used to alter storm runoff in such a manner so that the resulting influx of runoff would have a minimal effect on combined sewer systems. This concept may include surface housekeeping to prevent solids from entering sewers (34); capturing storm runoff from buildings to use for lawn sprinkling or increased fire protection; zoning and site grading restrictions to increase time of concentration and decreases the solids load of the runoff (50); throttling of catch basin inlets to restrict inflow into the system; utilizing porous pavement to reduce runoff (51); or employing any other method to reduce pollutional inflow to the sewer.

The concept of surface drainage area control must be considered a part of urban runoff management. Although this concept will not provide for a direct solution to the problem of combined sewer overflows, its application will help alleviate the problem and control the tendency toward the ever-increasing effect of runoff from urbanized areas.

Off-Line Storage

In this context, off-line storage is used to connote the storage of combined sewer wastewater during wet weather periods in holding facilities located at or near outfalls. These facilities may include rigid or flexible tanks, deep tunnels or ponds, and they may or may not have provisions for treatment of volumes in excess of their capacity. The major problems encountered by these storage facilities are land costs and availability, adverst aesthetic impacts, operating costs and solids removal (52).

As in the case of combined sewer overflow treatment, land availability is one of the major limiting factors in the installation of retention facilities. The only possible location in the Detroit area for retention facilities are in parks along the Rouge River and in a few park areas near the Detroit River. However, many of these locations are wooded areas and the possible destruction of large segments of the parkland would not be desirable.

In-System Storage

In-system storage has been defined as the utilization of excess capacity in the trunk and interceptor sewers (52). Although this definition describes the concept used in this project, it should be expanded to include any storage facility which may be used to carry dry weather flow but, which through some mechanical means, may also be used to store storm wastewater flow. The Livernois Relief Sewer as discussed earlier, would not be considered as an in-system storage facility until the modifications mentioned were made.

ANALYSIS OF ALTERNATIVES

As in the case of others (53), separation of sewers was not considered to be a practical approach to the solution of combined sewer overflows. Not only is this alternative of tremendous cost, but there is no assurance that all cross-connections between sanitary and storm sewers will be eliminated or that future illegal connections would not be made. In addition, urban storm runoff is polluted and it would not seem logical to allow this polluted runoff to enter the receiving waters. For these reasons, separation of sewers into sanitary and storm is not justifiable.

Given the existing technology in the treatment of combined sewer overflows, it appears that a suitable method for treating large flows has not been developed. In addition, maintenance requirements and sludge handling techniques are not suitable for the Detroit system with its relatively large number of outfalls and diversity of location. It may be argued that some treatment is better than no treatment. Although this is a valid point, after analysis of the results of this project and others, it is believed that the monies involved could be better spent in the capturing of storm flow and subsequent higher degree of treatment at a wastewater treatment plant.

Surface drainage area control is dependent upon the support of the general public and those in all levels of government. Zoning and building code changes designed to alleviate either the volume or the pollutional load of runoff must have general support. The need for neighborhood surface housekeeping and judicious use of pesticides and fertilizers must be impressed upon the general public. Engineers who are a part of the DMWD speakers group have found that large segments of the public are unaware as to individual and group action that may be taken to reduce pollution although almost all are aware that a pollution problem exists. It appears that, as public awareness of individual pollution control actions increase, this method of aiding in the reduction of pollution from combined sewer overflows will play an increasingly important role.

Off-line retention basins have been considered for several locations in the Detroit system where land is available. The economic analysis of this type of facility is based on the costs for four retention basins which have been constructed in the Detroit area. These basins are all located near outfalls and range in size from 7 million gallons to 62 million gallons. One basin is gravity filled and dewatered while the others require pumpage for dewatering. Figure 83 shows the estimated cost for a retention facility that contains a skimming weir overflow, facilities for chlorination of excess volumes and hydraulic flushing (54). The costs shown have been updated to 1971 using the Engineering News Record Construction Cost Index. The first cost of the four basins ranges between $0.20/gallon and $0.50/gallon based on 1971 costs.

The major problem with all retention facilities is the deposition of solids. These solids may be removed mechanically or manually or may be flushed back into the system either hydraulically or by mechanical resuspension. All of these methods add to operation and maintenance costs. In addition, combined sewers have been found to contain such items as 12 foot long timbers, 5 gallon pails, 6 inch globe valves, large chunks of concrete, oxy-acetylene tanks, step ladders and miscellaneous debris which would be difficult to remove from basins or screening devices without some manual cleaning. Any on-site cleaning results in a solids waste disposal problem, and these disposal costs must be included in the operation of the facility.

The demonstration project has resulted in a controlled storage volume of approximately 140 million gallons at a 1971 cost of about $2.7 million or about $0.02/gallon of storage. This figure cannot be compared with that of retention basins since it was based on the use of existing capacity in the system. In addition, the locations used for storage were selected based on maximum storage at minimum cost. Additional in-system storage locations have been investigated and the costs have increased to about $0.06/gallon. It is expected that, as the system is utilized more fully, these costs for added increments of storage will continue to rise.

It is also evident that the capacity for in-system storage does not exist in every district in the system, and the problem of capturing storm flow will still exist. As a solution to this problem, DMWD is considering the construction of additional sewers to be used for storage and to provide relief capacity during severe storms. Figure 84 shows the estimated 1971 cost of sewers. Costs were derived from previous tunnel and open-cut sewer and water main construction contracts (55). In certain areas of Detroit, open-cut construction could be used to add additional barrels to existing sewers in an arrangement similar to the Conner Gravity Sewer. In other areas, tunnel construction would be necessary. The cost/gallon of the larger sewers is competitive with those costs shown for retention basins. In addition, by using dry weather flow for flushing, the operating costs will be considerably less than for retention basins.

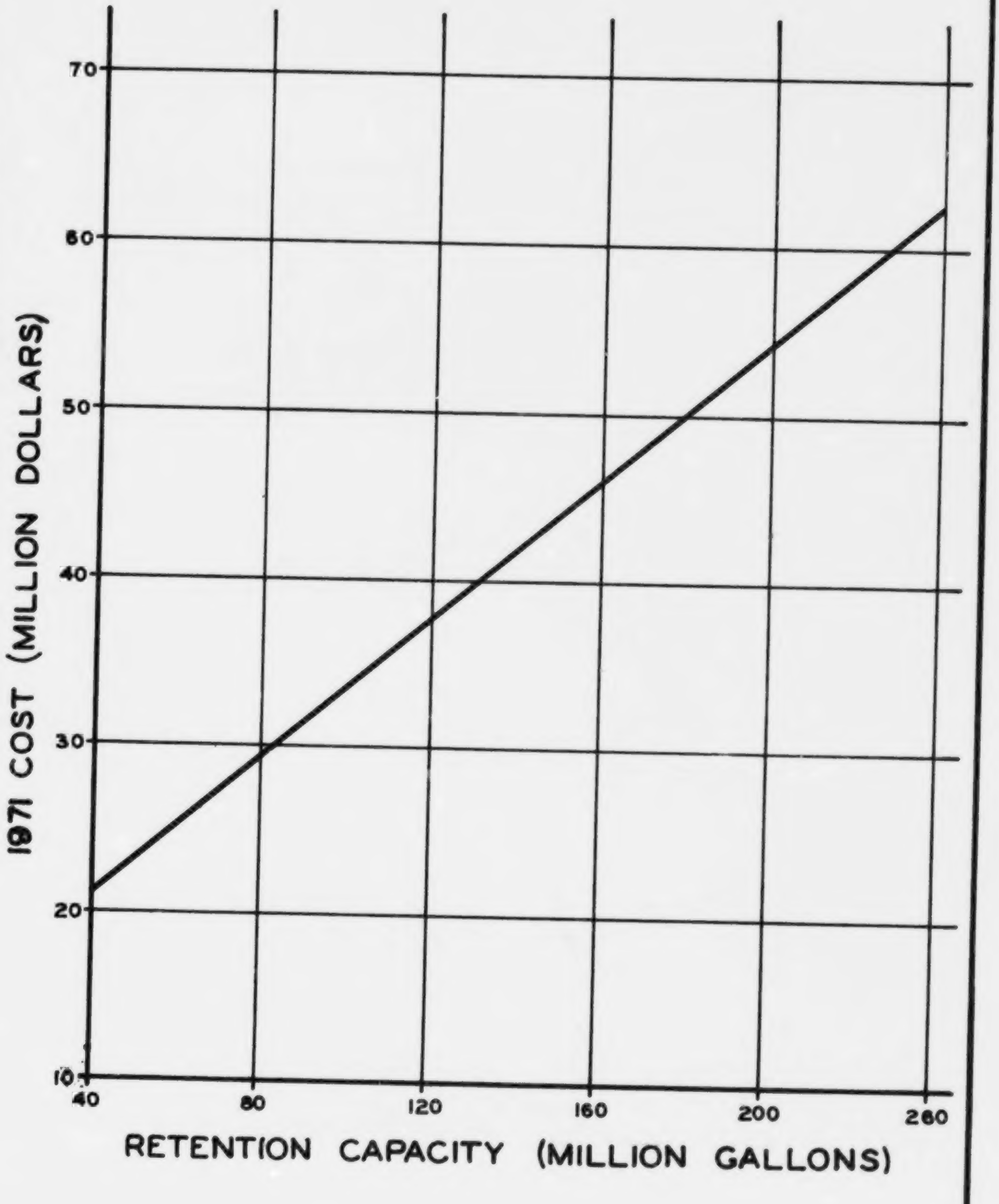


Figure 83-ESTIMATED COST OF RETENTION FACILITIES

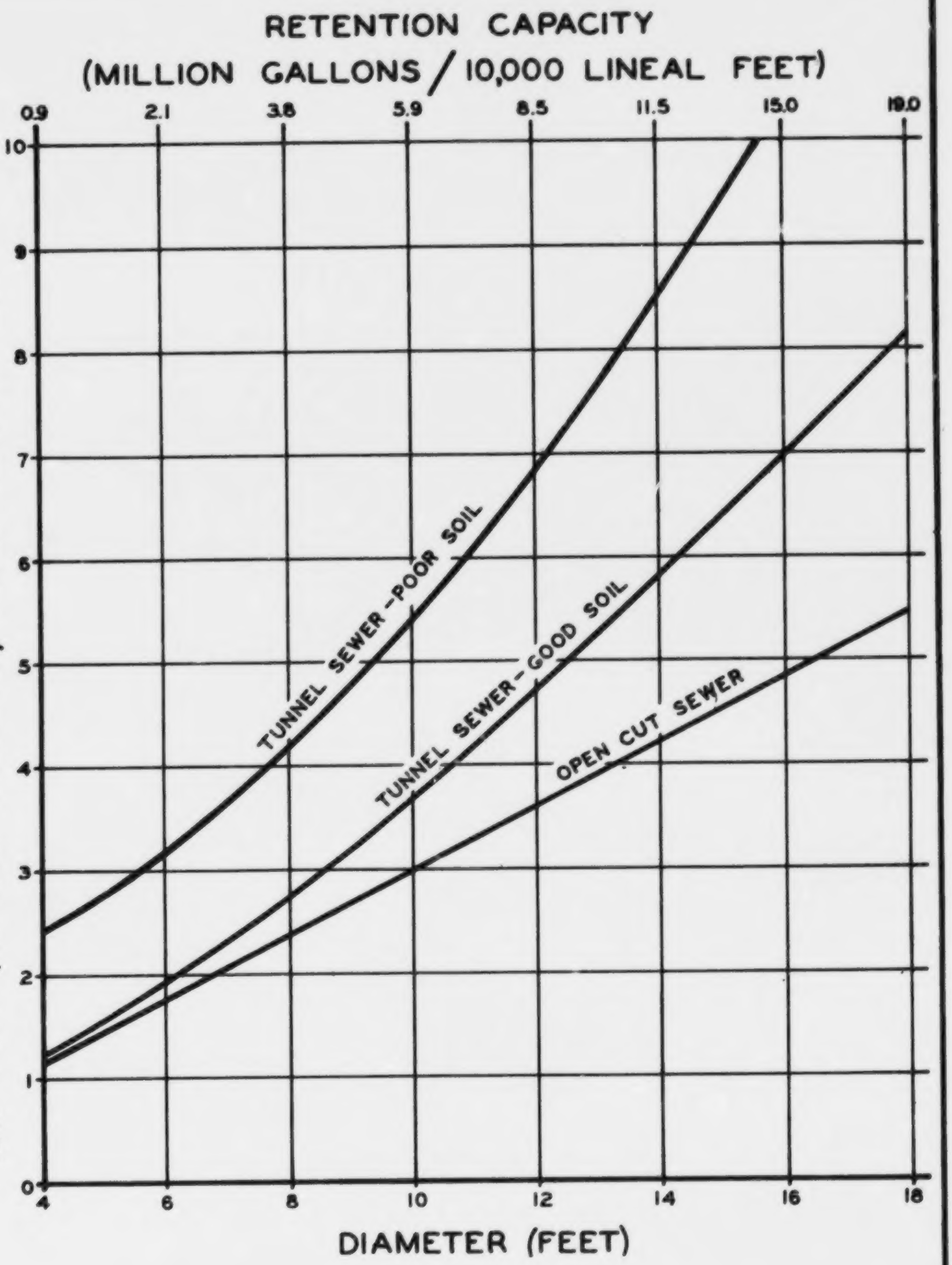


Figure 84-ESTIMATED COST OF SEWERS

An additional benefit to in-system is the flow routing capability. Many of the sewers in the Detroit system are over 50 years old. The Detroit River Interceptor was constructed in 1929 while other large sewers were constructed around 1900. These sewers will need to be rebuilt eventually. At the present time, if one of the major sewers fails, raw sewage may have to be routed to the river. With multiple cross-connections similar to water distribution systems, flow could be routed around failures or areas of rebuilding without the necessity of dumping raw sewage into the receiving streams or the necessity of costly pumping of the wastewater around the failure area.

Based on the experience obtained under this demonstration project, it is believed that in-system storage can provide an economical solution to the problem of pollution resulting from combined sewer overflows. Although first costs for additional open-cut or tunnel sewer construction may be greater than retention facilities, it is believed that this approach will be more economical on a long-term basis when operating and maintenance costs are considered.

SECTION XI

ADDENDUM

Since the end of the evaluation period in August, 1971, the Detroit Metro Water Department (DMWD) has continued the evaluation and expansion of the original monitoring project. This section will serve to update some of the information contained in the report and to highlight work which has been done since the original evaluation period.

MONITORING EQUIPMENT MODIFICATIONS AND ADDITIONS

Rain Gages

The network of 14 tipping bucket rain gages has been expanded to a 25 gage network. Several of the new gages were added within the City of Detroit to increase the existing network density. In addition, gages were installed in some of the westerly and northerly suburban communities to aid in the operation of their systems. All gages are now equipped with 500 watt heaters and frequency shift telemetry devices. It is believed that both the accuracy of data transmission and the calculation of expected runoff will be enhanced by these additions and modifications.

Radar Remoting System

As a supplement to the rain gage data, a radar remoting system to provide instant weather information by telephone lines has been installed in the Systems Control Center. The radar system displays the weather pattern within a 125 mile radius of the Detroit Metro Airport.

Experience to date has shown that once a storm approaches within about 50 miles of Detroit, it is relatively certain that the storm will affect the wastewater collection system. Pumpdown procedures are now initialized whenever a storm is between the 25 and 50 mile radii circles on the display.

Level Sensors

The level sensor network has been expanded and a total of 214 sensors are now in place. All of the new sensors have a 15 second cycle time and most sensors have a 0-20 feet range. Thirty of the new sensors have been installed in various suburban sewer systems and retention basins to facilitate dewatering operations and coordination of system operations. Some of these levels are telemetered to both the DMWD Systems Control Center and to suburban control centers.

Status Sensors

Additional status sensors have been installed at overflow points which have multiple backwater gates or dams. Thus, if any one of the gates opens, an overflow will be recorded for that location. Overflow status sensors have also been installed on several suburban systems to provide data to those communities on the frequency and duration of their overflows. A total of 110 overflow points are now monitored.

COMPUTER SYSTEM

The existing data logger was replaced with a Control Data SC1700 computer system. The central processor has 24K core and a 3 million word cartridge disk subsystem. The mass storage operating system is stored on a 1.5 million word fixed disk and sensor data will be stored on removable cartridge disks. These data disks will be taken to the Wastewater Treatment Plant for processing of monitoring data utilizing the SC1700 systems being installed there for process control.

Data logging at the Systems Control Center consists of hourly printouts of level sensor readings, rainfall totals, and hourly intensities. Overflow status changes and pump status changes will be logged in real time. In addition, a daily summary of pump running hours, total rainfall, and overflow signal malfunctions will be printed at 2400 hours. Output format of the logs has been changed to allow easier identification of sensor points.

The operator interface to the system consists of a CRT and an alarm printer. The wastewater collection system has been divided into 12 subsections. A schematic plan view of the major sewers and level sensor locations within a subsection are displayed at the top of each CRT page. The bottom half of the page displays the level sensor data for the preceding three 5 minute intervals, three 15 minute intervals, and seven 60 minute intervals for a total of 8 hours of data. The latest 5 minute rainfall intensity and daily total rainfall for any rain gage located within the subsection is also displayed on the appropriate page. The system is designed to display a total of 30 pages. However, only 19 pages of sensor data are being utilized at the present time.

Alarms are logged on a Selectric Typewriter. All points going into alarm are logged in red. Returns from alarm or other system occurrences are logged in black. In addition, all alarms must be acknowledged by the operator using the CRT keyboard. Unacknowledged alarms are reprinted every 5 minutes until acknowledged.

SUPERVISORY CONTROL SYSTEM

The supervisory control system has been expanded with the addition of four new control panels to the three existing panels installed under the grant project. Remote control facilities including three wastewater pump stations, four interceptor regulators, three fabridams, two in-system storage gates, one flow routing gate, and one suburban connection have been added to the supervisory control system. In addition, four suburban retention basins and 11 suburban pump stations are displayed schematically with basin levels and pump status indicated.

PUMP STATIONS

Supervisory Control

The eight 500 cfs storm pumps at the Conner Pump Station were remotely controlled shortly after the end of the project. Since the pumps have raised impellers, they must be primed. In addition, an exciter is used for each pair of pump motors and must be running prior to pump starting. A single push-indicating switch is used to sequence operations for each pump. The switch is turned to the "start" position and pushed. This causes the exciter to start if it is not already running. When the exciter is running, the "running" light on the switch is lit. After about one minute the switch is depressed again to start the pump motors and the automatic priming sequence. The "running" light turns off to confirm that the priming sequence has started. Approximately 6 to 8 minutes later when the vacuum in the pump casing reaches 24" Hg, a limit switch shuts the vacuum pump off and the "running" light is lit to confirm that the pump priming sequence has terminated.

Operators have indicated that the above procedure has led to some difficulties. The major problems are the time required to start the pumps and the possible failure of the pumps to prime correctly. As discussed in Section IX, the operators are quite active during storm events. The time lag associated with starting the storm pumps forces the operators to anticipate the number of pumps required to prevent upstream flooding. Furthermore, the operator must remember the status of each pump in the starting sequence. Once an indication that the pump has started is received, the operator must then observe the wet well level indicators to determine if the pumps have been primed correctly and are actually pumping wastewater.

Two other pump stations have been completed since the grant period ended and both are remotely controlled. One station contains 3-40 cfs pumps and one standby pump. The other station currently has 2-150 cfs and 1-100 cfs pumps. The operation of these stations is the same as the stations remotely controlled under the original grant project.

Pump Station Discharge Conduit Modifications

All flow from the easterly service area of the DMWD must be pumped through the Fairview Interceptor Lift Station. The service area of this station is shown in Figure 3. Prior to monitoring, the station was shut down during storm events and the Conner and Freud storm pumps were used to prevent most flow from reaching the station.

After several months of operation of the system utilizing monitoring and remote control, it became apparent that the Fairview Station could be operated during storms without significantly affecting the system downstream of the station. This was especially true for spot storms which occurred over the easterly portion of the service area. In addition, over 100 million gallons of wastewater could be stored in the easterly service area during a storm event and it was noted that 3 to 4 days were required to dewater the system.

Although Fairview has a pumping capacity of 525 cfs, it was rarely operated at more than 300 cfs prior to monitoring. Normal operation ranged between 75 and 225 cfs. Previous reports had indicated that surge problems could be anticipated at flows greater than 300 cfs.

Surge analysis studies indicated the magnitude of the problem. The results of these studies were verified by utilizing level sensor data and by field observation. The discharge conduit was inspected to determine its condition utilizing system shutdown procedures outlined in Section IX. Based on the level data and observations, various alternatives were introduced into the surge model for analysis. The results indicated that the most economical solution was to modify the discharge conduit as shown in Figure 85. An electrode sensor was installed on the surge overflow wier and the status is displayed on the control panel in the Systems Control Center.

Although the station has been in operation for only a few months since it was modified, sufficient information is available to indicate that the surge problem has been eliminated when the station is pumping at its 525 cfs capacity. Level and surge overflow data may be used to further refine the model so that it may be used in other applications if necessary.

The Oakwood Pump Station serves the district shown in Figure 3. The 3'-0" discharge conduit as detailed in Figure 23 enters the system just upstream of the Rouge River siphons. The conduit was originally designed with a capacity equal to one sanitary pump. During storm events, the sanitary wastewater pump was shut down and only storm pumps were utilized. With the change in philosphy of system operation, the sanitary pump was operated during storm events in order to capture as much flow as possible.

Monitoring data indicated that the system should be capable of accepting the flow from both sanitary pumps during storms. Pumping records were analyzed and it was determined that, as an average, approximately 4 million gallons per storm event could be pumped to the wastewater treatment plant if both sanitary pumps were operated.

To implement this mode of operation, the only modifications necessary were the installation of weighting collars and gasketed manhole covers on two manholes so that the discharge conduit could be used as a force main.

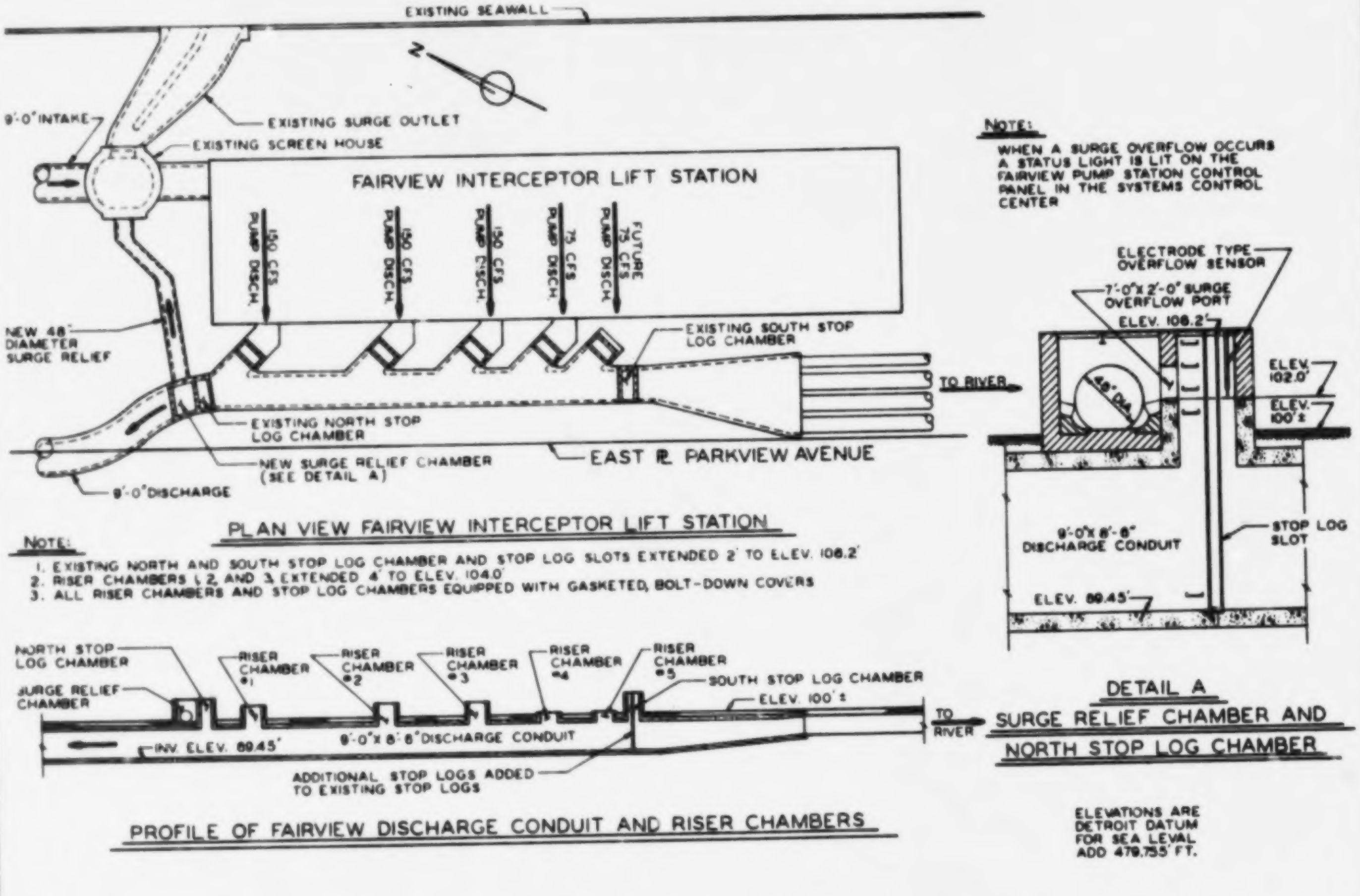

EXISTING SEAWALL
N
9'-0" INTAKE
EXISTING SURGE OUTLET
EXISTING SCREEN HOUSE
FAIRVIEW INTERCEPTOR LIFT STATION
150 CFS PUMP DISCH.
150 CFS PUMP DISCH.
150 CFS PUMP DISCH.
75 CFS PUMP DISCH.
FUTURE 75 CFS PUMP DISCH.
NEW 48" DIAMETER SURGE RELIEF
EXISTING SOUTH STOP LOG CHAMBER
TO RIVER
EXISTING NORTH STOP LOG CHAMBER
NEW SURGE RELIEF CHAMBER (SEE DETAIL A)
EAST ℄ PARKVIEW AVENUE
9'-0" DISCHARGE
PLAN VIEW FAIRVIEW INTERCEPTOR LIFT STATION
NOTE:
1. EXISTING NORTH AND SOUTH STOP LOG CHAMBER AND STOP LOG SLOTS EXTENDED 2' TO ELEV. 106.2'
2. RISER CHAMBERS 1, 2, AND 3 EXTENDED 4' TO ELEV. 104.0'
3. ALL RISER CHAMBERS AND STOP LOG CHAMBERS EQUIPPED WITH GASKETED, BOLT-DOWN COVERS
NORTH STOP LOG CHAMBER
SURGE RELIEF CHAMBER
RISER CHAMBER #1
RISER CHAMBER #2
RISER CHAMBER #3
RISER CHAMBER #4
RISER CHAMBER #5
SOUTH STOP LOG CHAMBER
ELEV. 100'±
INV. ELEV. 89.45'
9'-0" X 8'-8" DISCHARGE CONDUIT
ADDITIONAL STOP LOGS ADDED TO EXISTING STOP LOGS
TO RIVER
PROFILE OF FAIRVIEW DISCHARGE CONDUIT AND RISER CHAMBERS
NOTE:
WHEN A SURGE OVERFLOW OCCURS A STATUS LIGHT IS LIT ON THE FAIRVIEW PUMP STATION CONTROL PANEL IN THE SYSTEMS CONTROL CENTER
ELECTRODE TYPE OVERFLOW SENSOR
7'-0" X 2'-0" SURGE OVERFLOW PORT
ELEV. 106.2'
48" DIA.
ELEV. 102.0'
ELEV. 100'±
9'-0" X 8'-8" DISCHARGE CONDUIT
STOP LOG SLOT
ELEV. 89.45'
DETAIL A
SURGE RELIEF CHAMBER AND NORTH STOP LOG CHAMBER
ELEVATIONS ARE DETROIT DATUM FOR SEA LEVAL ADD 479.755' FT.

Figure 85 - FAIRVIEW DISCHARGE MODIFICATIONS

REGULATOR MODIFICATIONS

Leib Street Regulator

The Leib Street regulators transfer flow from the Conant-Mt. Elliot combined sewer, as shown in Figure 17, to the Detroit River Interceptor. At this point, two 11'-0" diameter barrels discharge into a regulator chamber containing four No. 12 Brown and Brown float controlled regulators. Overflow monitoring data indicated that this sewer had the highest frequency of overflows among the monitored points. Level sensor data indicated that under certain conditions the regulators could have been kept open longer to permit additional flow to be diverted to the interceptor.

Remotely operated hydraulic cylinders were installed on each regulator gate. A typical installation is shown in Figure 86. Note that the existing float mechanism was modified by the installation of a counterweight on each float. This serves to relieve the load on the cylinder and also to open the regulator if the cylinder were to fail.

McClellan-Cadillac Regulator

The McClellan-Cadillac regulator serves the 6'-3" McClellan combined sewer and the 5'-9" Cadillac combined sewer utilizing two 24-inch, Type "C", McNulty regulators. The regulators operated as a function of the depth of flow in both the McClellan and Cadillac sewers and the Detroit River Interceptor. The regulators were set to be completely closed when the elevation in the float chamber reached elevation 99.0 feet Detroit datum. The McClellan sewers' overflow weir is at elevation 98.0 feet and the Cadillac sewers' at elevation 98.5 feet.

The regulator chamber is located approximately 2000 feet downstream of the Fairview Interceptor Lift Station. It was found that flow from the interceptor will sometimes back up through the regulator chamber and top the overflow weirs when the Fairview pump station is operated during storm events.

The regulator has been modified for remote control as shown in Figure 87. Since the regulator was built in 1927, it was decided to remove the existing float mechanism and gate and install new sluice gates as shown. With the exception of the telemetering equipment, all control equipment was located within one of the existing float chambers. A sump pit, sump pump and dehumidifier were installed in the chamber.

Dearborn Regulator

Due to the expansion at the Wastewater Treatment Plant, the Portland-Harbaugh (Pulaski) Sewer was relocated to the Dearborn sewer. The outfall and regulator chamber at Dearborn were replaced with larger capacity facilities. As shown in Table 8, neither of the outfalls experienced overflows. This was due to both the decrease in service area of the

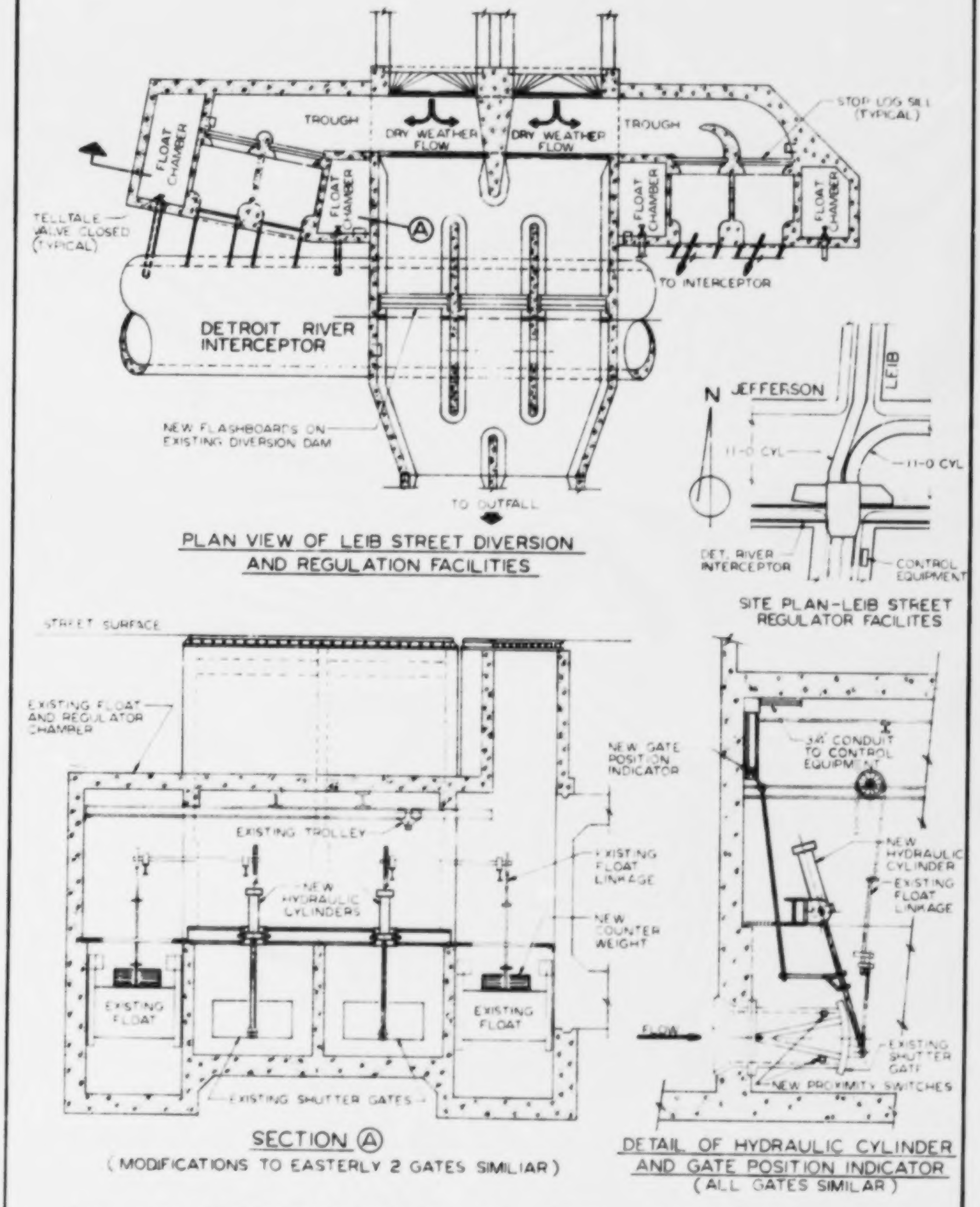


Figure 86-MODIFICATIONS AT THE LEIB REGULATOR

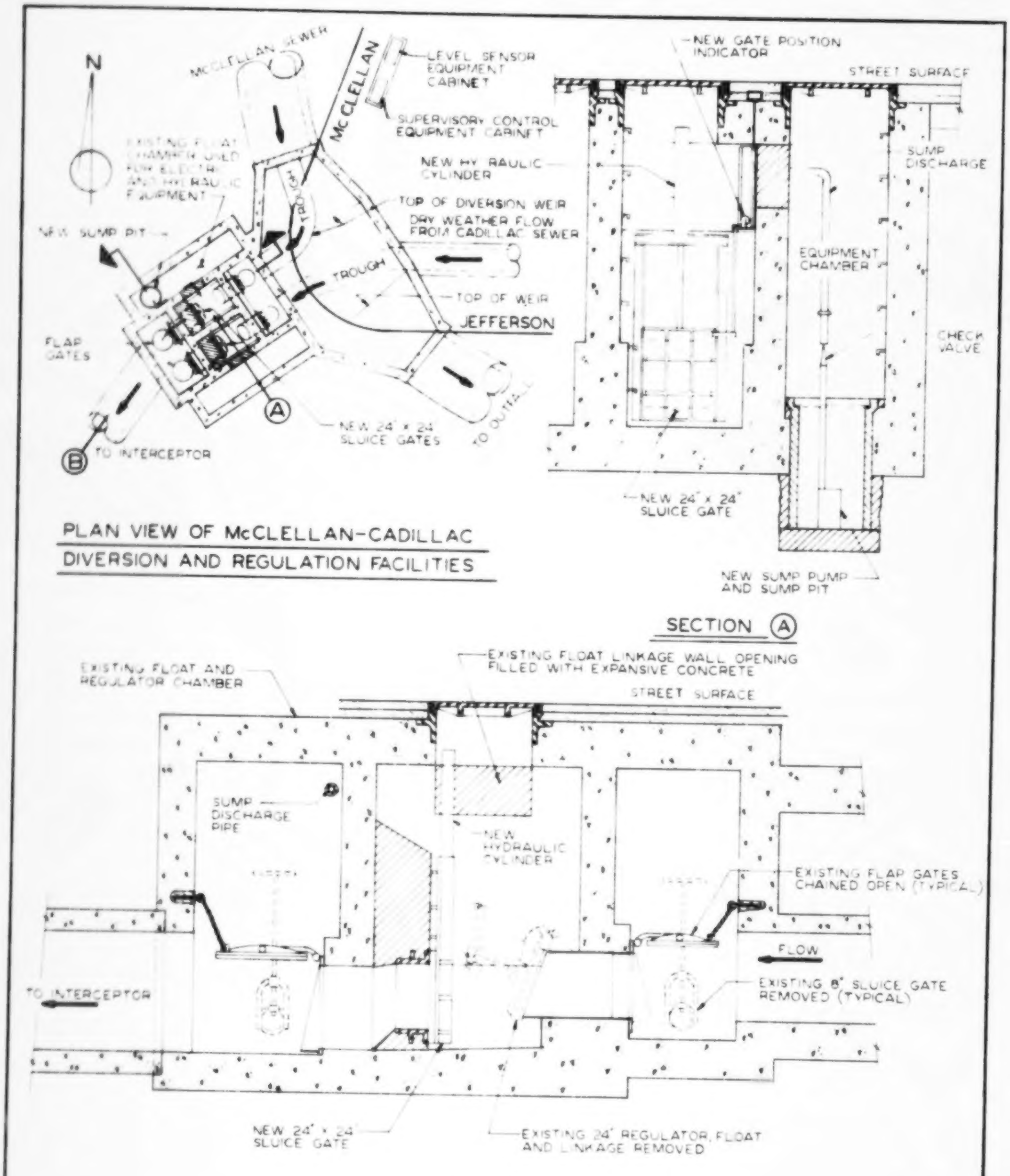

N
McCLELLAN SEWER
McCLELLAN
LEVEL SENSOR EQUIPMENT CABINET
SUPERVISORY CONTROL EQUIPMENT CABINET
EXISTING FLOAT CHAMBER USED FOR ELECTRIC AND HYDRAULIC EQUIPMENT
NEW HYDRAULIC CYLINDER
TROUGH
TOP OF DIVERSION WEIR
DRY WEATHER FLOW FROM CADILLAC SEWER
NEW SUMP PIT
TROUGH
TOP OF WEIR
JEFFERSON
FLAP GATES
A
NEW 24" x 24" SLUICE GATES
TO OUTFALL
B
TO INTERCEPTOR
PLAN VIEW OF McCLELLAN-CADILLAC DIVERSION AND REGULATION FACILITIES
NEW GATE POSITION INDICATOR
STREET SURFACE
SUMP DISCHARGE
EQUIPMENT CHAMBER
CHECK VALVE
NEW 24" x 24" SLUICE GATE
NEW SUMP PUMP AND SUMP PIT
SECTION A
EXISTING FLOAT AND REGULATOR CHAMBER
EXISTING FLOAT LINKAGE WALL OPENING FILLED WITH EXPANSIVE CONCRETE
STREET SURFACE
SUMP DISCHARGE PIPE
NEW HYDRAULIC CYLINDER
EXISTING FLAP GATES CHAINED OPEN (TYPICAL)
FLOW
TO INTERCEPTOR
EXISTING 8" SLUICE GATE REMOVED (TYPICAL)
NEW 24" x 24" SLUICE GATE
EXISTING 24" REGULATOR, FLOAT AND LINKAGE REMOVED
SECTION B

Figure 87 - MODIFICATIONS AT THE McCLELLAN CADILLAC REGULATOR

sewers due to plant expansion and to the fact that the float operated regulators do not close because of drawdown in the interceptor.

For the above reasons, remote control facilities were installed on the regulator under the relocation work. It is anticipated that following the first flush interception during a storm event, the regulator will be closed to allow in-system storage. It will then be modulated to prevent an overflow while maximizing storage.

Evergreen-Farmington Regulator

The Evergreen-Farmington regulator and meter chamber is located at the north end of the Southfield Sewer (Figure 17). The combined sewer discharge from this suburban connection is regulated by a telltale into the Southfield Sewer. In order to protect the Detroit system from excessive flows, the regulator closes during storm events and causes this suburban flow to overflow into the Rouge River.

Monitoring data indicated that on many occasions, storms would pass over the northwest corner of Detroit. Because of the inflow into the Detroit system, the suburban regulator would close even though additional capacity existed in the Detroit System further downstream. In an attempt to reduce the overflow problem at this location, a remotely controlled override has been installed on the regulator so that additional flow may be taken into the Detroit system when conditions permit. The overflow status is also indicated on the control panel in the DMWD Systems Control Center so that the operators know if an overflow is occurring and may perhaps be able to open the regulator gate to accept additional flow.

Hubbell-Southfield Fabridams

As discussed in Section X, the Hubbell-Southfield 14'-6" x 12'-0" double box sewer had a storage potential of about 23 million gallons although only about 3.5 million gallons was utilized. A 6'-3" fabridam was installed in each barrel of the sewer immediately upstream of the backwater gates to fully utilize the sewer's storage potential. The installation is similar to the Minneapolis-St. Paul fabridams (27).

A condensate water drain line, an 8-inch diameter blow-off standpipe and dam pressure telemetry devices as suggested by Minneapolis were installed. In addition, the dam controls were designed for automatic on-site operation with override controls at the Systems Control Center. The dams will modulate automatically to maintain the level in the sewer at 2 feet below crown. If the wastewater level continues to rise to within 18 inches below the crown, a second solenoid valve will open. At 12" below crown, a spring loaded relief valve opens and the blow off standpipe is activated. Since Minneapolis reported that surges tended to activate their blow-off, the DMWD standpipes were equipped with submergence limiters to allow adjustment of the blow-off standpipe water level should loss of standpipe water become a problem.

Livernois-Relief Sewer Modifications

The possible utilization of the Livernois Relief Sewer (Figure 80) for in-system storage was discussed in Section X. Approximately 8 million gallons of in-system storage was obtained by the installation of remote control facilities at four locations on the sewer. These included 1-cross connection gate, 2-storage gates, 1-fabridam, and modifications to the regulator. The details of these installations are shown in Figures 88 and 89.

Two electrically operated 78" x 78" sluice gates were installed at Warren Avenue. Electric operators were selected for the same reasons as outlined in previous sections of this report. Emergency manual overrides and a plastic stem cover were installed. In addition, plastic grating was installed on the motor support floor to provide some relief capacity if both gates should fail and the emergency crew is delayed.

The farridam installation at Ranspatch Avenue utilizes the same type of control scheme as that described for the Hubbell-Southfield Fabridams.

DATA UTILIZATION

The utilization of the data obtained during the original study period was described in Sections IX and X. In general, the DMWD has continued to apply the data in a similar manner. Other uses of the data which have been investigated or are currently being implemented will be briefly discussed here.

Flow in Sewers and Overflow Volumes

Attempts to correlate sewer levels with flow and to calculate overflow volumes have not been greatly successful. The locations selected for the majority of level sensors were areas where operational information was desired. In general, these locations are either upstream or downstream of major connections or relief ports; upstream of control facilities; in pump station wet wells; or near transition sections. As a result, flow calculations based on depth of flow in open channels have not yielded reliable information. The major error source is backwater effect which tends to yield much higher calculated flow values than would be expected.

In those locations where there is a relatively long reach of sewer upstream and downstream of the level sensor so that "normal depth of flow" conditions may be assumed, flow predictions based on depth of flow appear to be reliable. However, in some of the older sewers, movement of the sewer and/or construction procedures have changed assumed values for the slope and as a result affected flow calculations. This was evidenced in cases where upstream flows were higher than downstream flows when calculated from level data.

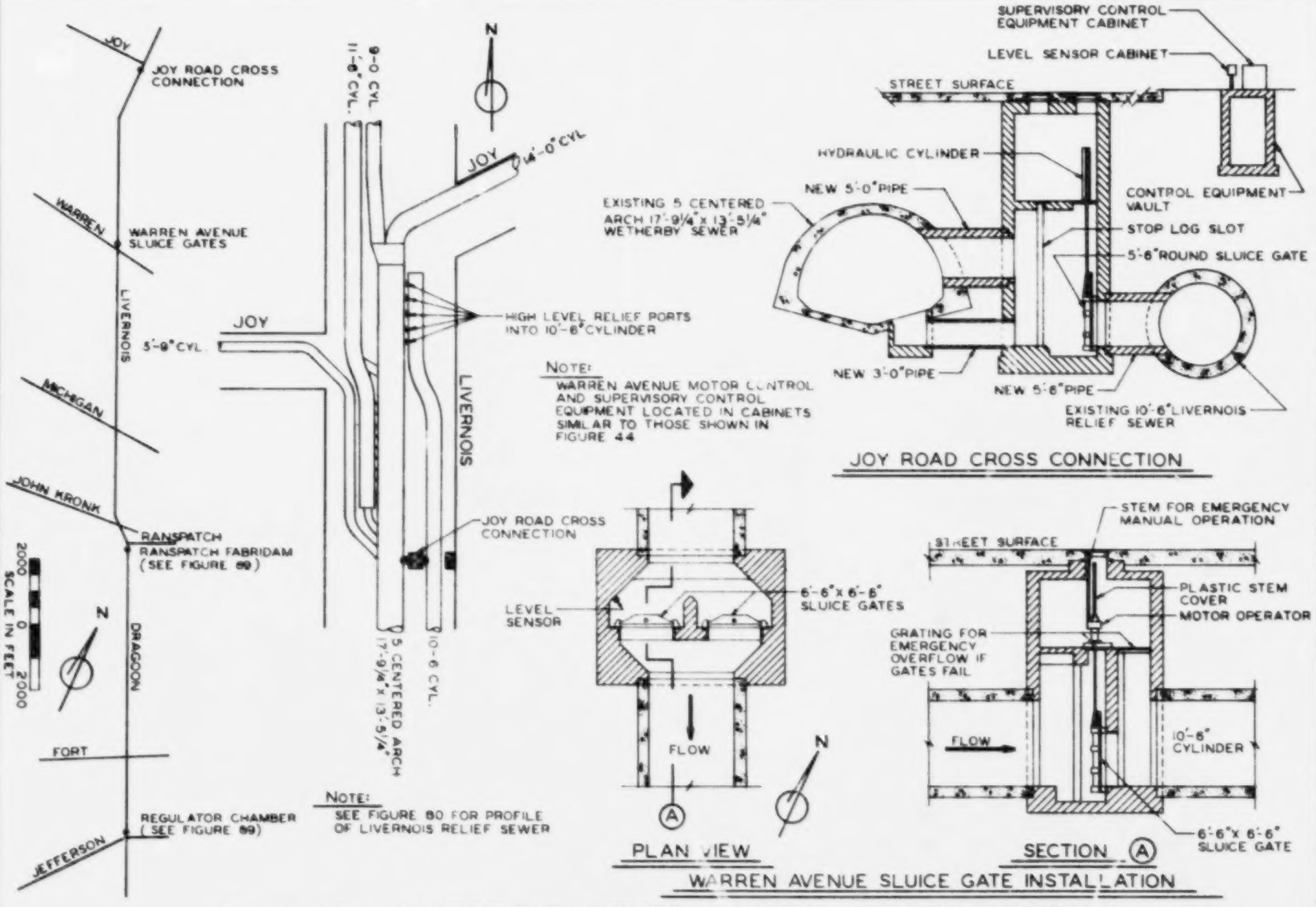
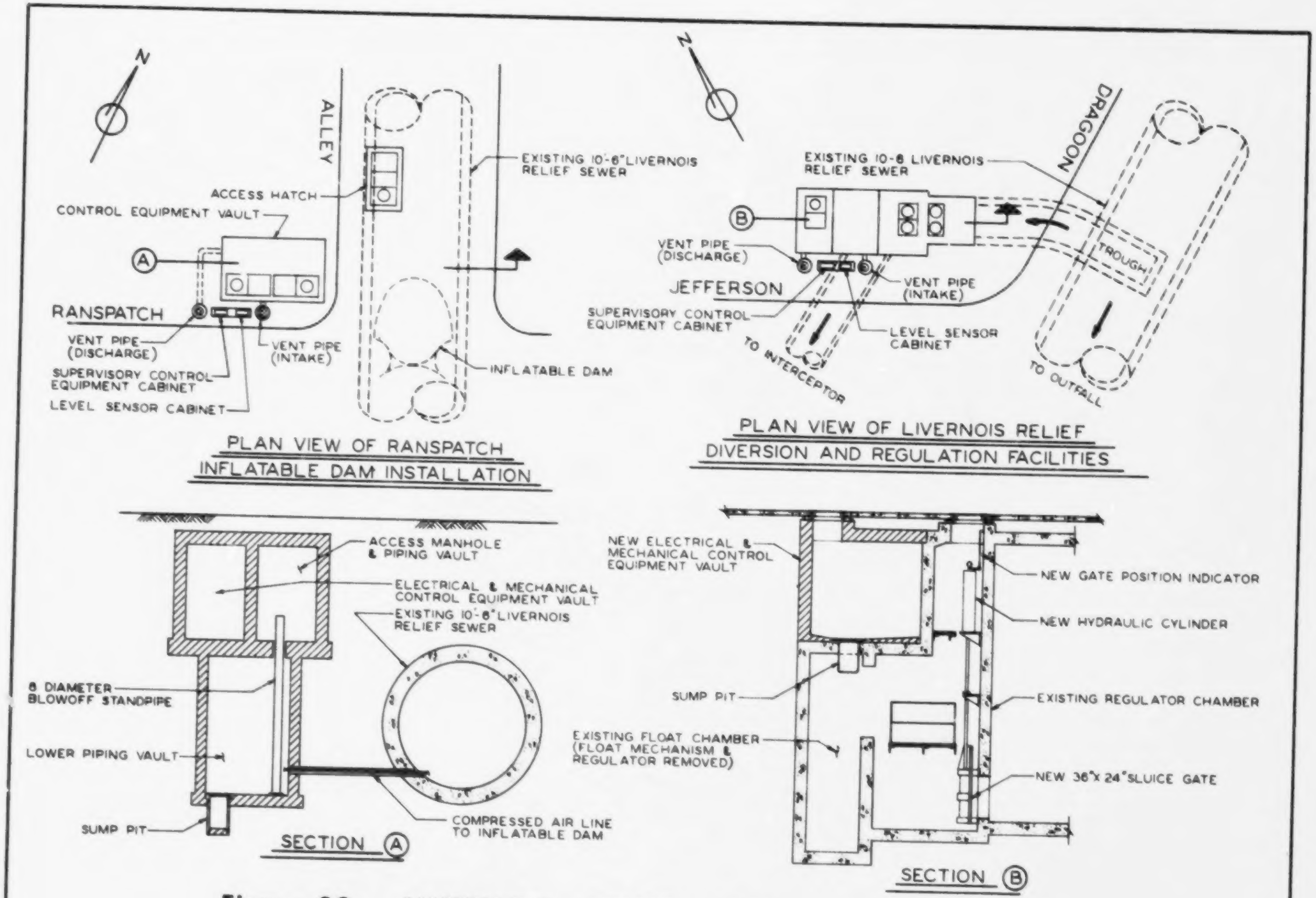

JOY
JOY ROAD CROSS CONNECTION
WARREN
WARREN AVENUE SLUICE GATES
LIVERNOIS
MICHIGAN
JOHN KRONK
RANSPATCH
RANSPATCH FABRIDAM (SEE FIGURE 89)
DRAGOON
FORT
REGULATOR CHAMBER (SEE FIGURE 89)
JEFFERSON
N
2000 0 2000
SCALE IN FEET
9-0 CYL.
11-6" CYL.
JOY
14'-0" CYL
5'-9" CYL.
LIVERNOIS
HIGH LEVEL RELIEF PORTS INTO 10'-6" CYLINDER
JOY ROAD CROSS CONNECTION
5 CENTERED ARCH 17'-9¼" x 13'-5¼"
10-6 CYL.
NOTE:
SEE FIGURE 80 FOR PROFILE OF LIVERNOIS RELIEF SEWER
NOTE:
WARREN AVENUE MOTOR CONTROL AND SUPERVISORY CONTROL EQUIPMENT LOCATED IN CABINETS SIMILAR TO THOSE SHOWN IN FIGURE 44
SUPERVISORY CONTROL EQUIPMENT CABINET
LEVEL SENSOR CABINET
STREET SURFACE
HYDRAULIC CYLINDER
NEW 5'-0" PIPE
EXISTING 5 CENTERED ARCH 17'-9¼" x 13'-5¼" WETHERBY SEWER
CONTROL EQUIPMENT VAULT
STOP LOG SLOT
5'-6" ROUND SLUICE GATE
NEW 3'-0" PIPE
NEW 5'-6" PIPE
EXISTING 10'-6" LIVERNOIS RELIEF SEWER
JOY ROAD CROSS CONNECTION
LEVEL SENSOR
6'-6" x 6'-6" SLUICE GATES
FLOW
A
PLAN VIEW
STEM FOR EMERGENCY MANUAL OPERATION
STREET SURFACE
PLASTIC STEM COVER
MOTOR OPERATOR
GRATING FOR EMERGENCY OVERFLOW IF GATES FAIL
FLOW
10'-6" CYLINDER
6'-6" x 6'-6" SLUICE GATE
SECTION (A)
WARREN AVENUE SLUICE GATE INSTALLATION

Figure 88 - LIVERNOIS RELIEF SEWER MODIFICATIONS AT JOY AND WARREN


PLAN VIEW OF RANSPATCH INFLATABLE DAM INSTALLATION

PLAN VIEW OF LIVERNOIS RELIEF DIVERSION AND REGULATION FACILITIES

SECTION Ⓐ

SECTION Ⓑ

N
ALLEY
ACCESS HATCH
CONTROL EQUIPMENT VAULT
Ⓐ
RANSPATCH
VENT PIPE (DISCHARGE)
SUPERVISORY CONTROL EQUIPMENT CABINET
LEVEL SENSOR CABINET
VENT PIPE (INTAKE)
EXISTING 10'-6" LIVERNOIS RELIEF SEWER
INFLATABLE DAM
N
DRAGOON
EXISTING 10-6 LIVERNOIS RELIEF SEWER
Ⓑ
VENT PIPE (DISCHARGE)
JEFFERSON
SUPERVISORY CONTROL EQUIPMENT CABINET
VENT PIPE (INTAKE)
LEVEL SENSOR CABINET
TROUGH
TO INTERCEPTOR
TO OUTFALL
ACCESS MANHOLE & PIPING VAULT
ELECTRICAL & MECHANICAL CONTROL EQUIPMENT VAULT
EXISTING 10'-6" LIVERNOIS RELIEF SEWER
8 DIAMETER BLOWOFF STANDPIPE
LOWER PIPING VAULT
SUMP PIT
COMPRESSED AIR LINE TO INFLATABLE DAM
NEW ELECTRICAL & MECHANICAL CONTROL EQUIPMENT VAULT
NEW GATE POSITION INDICATOR
NEW HYDRAULIC CYLINDER
SUMP PIT
EXISTING REGULATOR CHAMBER
EXISTING FLOAT CHAMBER (FLOAT MECHANISM & REGULATOR REMOVED)
NEW 36"X 24" SLUICE GATE

Figure 89- LIVERNOIS RELIEF SEWER MODIFICATIONS AT RANSPATCH AND JEFFERSON

By utilizing the energy equation for gradually varied flow, backwater effects may be considered in flow calculations. However, very few level sensors are located in areas where a second boundary condition is known or can be reasonably approximated. It was originally anticipated that an "M curve" (56) could be generated to predict overflow volumes at outfalls having weirs. Iterative techniques assuming a flow over the weir and solving for the upstream level were considered but not implemented. Since flow through the regulator immediately upstream of the dam was difficult to predict and since there were connections into most of the major sewers between the level sensor and the weir, flow determinations would not have been accurate enough to justify the work involved in their determination.

System Response Predictions

The DMWD has four major objectives in the utilization of the sewer system monitoring data. These are: 1) to aid in the operation of the system; 2) to predict and verify system response to storm events; 3) to establish priorities for overflow abatement projects; and 4) to develop computer control algorithms for the various remote control facilities.

Because of the complexity of the Detroit sewer system with its multiplicity of subdistrict and district interconnections, only three sewer districts can be independently analyzed. As shown in Figure 3, the Bluehill and Oakwood Districts containing approximately 2200 and 1500 acres respectively have all flow pumped. The Puritan District containing about 500 acres has all sanitary flow pumped and has three gravity outfalls each with a diversion weir and backwater gate. Additional level sensors have been installed in these districts to provide system response data. One of these new level sensors was installed in the Bluehill District approximately 2000 feet downstream of an existing level sensor along a reach of sewer with no other inlet sewers. Although three levels are necessary to solve the equations of motion if errors in the assumed pipe friction, slope or level readings are to be accounted for (57), it is believed that the flows predicted by only two levels will be sufficiently accurate for system response predictions and control algorithm development

Acoustic Flow Meters

As additional aids in predicting system response, acoustic flow meters have been installed on two outfalls. One of these meters is located on the Conant-Mt. Elliot sewer downstream of the Leib Street remotely controlled regulators. The sewer has five level sensors at various points upstream of the regulator and one level sensor at the regulator facility as shown in Figures 17 and 23. In addition, level sensors have been installed on the Detroit River Interceptor both upstream and downstream of the regulator facility. This information should be sufficient to verify any sewer hydrographs which may be developed.

A second acoustic flow meter has been installed on the West Chicago Sewer Outfall. This outfall serves as a relief to both the Hubbell-Southfield

Sewer and the Northwest Interceptor. There are 16 level sensors on the various sewers that affect overflow volumes in this outfall. Although the sewer system is quite complex in this area with high level reliefs and various interconnections, it is anticipated that the system response in this area may be predicted and verified using the data.

Additional Storage Facilities

Currently, the DMWD is investigating both in-system and off-line storage in the Rouge River, Conner Creek and Fox Creek Districts as shown in Figure 6. Preliminary studies in the Rouge River District have indicated that at least two sewer systems are amenable to in-system storage. Modifications to the outfalls in these system by the installation of fabridams or other control devices are estimated to cost between $0.06 and $0.13 per gallon of additional in-system storage capacity. Based on rainfall and overflow duration data, the above modifications will reduce overflows by 50% to 75% for those sewers.

Off-line retention facilities are being investigated for the Conner Creek and Fox Creek Districts. The existing 100 million gallons of in-system storage will be augmented by off-line storage which could be in excess of 100 million gallons. Sensor data could not be used in the preliminary design of these facilities to predict the volume of overflow which could be expected for a given storm.

However, the data is being utilized to determine operational procedures for dewatering. As indicated previously, 3 to 4 days are required to dewater the existing storage facilities. Normally, the Conner Gravity System, Figure 7, is dewatered first followed by the Conner Pumped System and then the Freud System. Level data in the Interceptor and pump station records have indicated that the new facilities may be dewatered concurrently with the Conner Pumped and Freud Systems. Critical to the dewatering operation is the sizing of the dewatering pumps. With the data available, the pump selection may be optimized to provide maximum dewatering rates with a minimum affects on the system operation.

Flooding Complaints

The DMWD periodically receives complaints of flooded streets or backups of wastewater into basements. In general, investigation of these complaints indicates minor problems with either the lateral sewers or the individual householder's connection. Occasionally, however, several complaints from a sewer district are received. If the area is near one of the larger monitored sewers, the level and rainfall data is analyzed to determine if the problem is due to the system operation. Special emphasis is placed on areas where remote control facilities are located. To date, only one of these complaints could be traced to operational problems. In this case, surge in a sewer downstream of a pump station caused air and mist to blow through the holes in a manhole cover. After analysis of level data, inspection of the manhole and sewer, and interviews with the individual who reported the incident, it was concluded that the surge was not serious and that no change in operation was required. No other similar complaints have been received for the sewer in question.

Summary

The DMWD believes that the Sewer Monitoring and Remote Control Program has been an invaluable aid in the operation of the wastewater collection system. During the evaluation period, the emphasis was placed on system operation and maximization of in-system storage. As the operation of the system was refined, efforts have since been directed to utilization of the monitoring data in the determination of overflow abatement programs, analysis of system response, and design of additional facilities where the data has indicated relief sewers are necessary.

The emphasis in the report has been placed on the equipment installed, the reasons for the particular installation, and the evaluation of both the equipment and the utilization of the equipment. It is intended that this report may serve as a guideline for those contemplating either the installation of new monitoring and control facilities or the modification or expansion of existing facilities.

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SECTION XIV

GLOSSARY

backwater curve	The longitudinal shape of the water surface in a stream or open conduit where such water surface is raised or lowered above its normal level by a natural or artifical constriction.
backwater gate	A gate installed at the end of a drain or outlet pipe to prevent the backward flow of water or wastewater. Generally used on sewer outlets into streams to prevent backward flow during times of flood or high tide. Also called a tide gate.
biochemical oxygen demand - (BOD)	The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.
capacity	The quantity that can be contained exactly, or the rate of flow that can be carried exactly.
combined sewer	A sewer intended to receive both wastewater and storm or surface water runoff.
combined wastewater	A mixture of surface runoff and other wastewater such as domestic or industrial wastewater.
concentration time	The period of time required for storm runoff to flow from the most remote point of catchment or drainage area to the outlet or point under consideration.
CRT	Cathode ray tube. Television for visual data presentation.
cubic foot per second (cfs)	A unit of measure of the rate of liquid flow past a given point equal to one cubic foot in one second.
dewater	To drain or remove water or wastewater from an enclosure.
drainage basin	The area served by a sewer system or watercourse receiving storm and surface water.

dry weather flow	- The flow of wastewater in a combined sewer during dry weather. Such flow consists mainly of wastewater, with no storm wastewater included.
equivalent uniform depth (E.U.D.)	- The average amount of rainfall over an area developed from the constituent rain gage stations and their associated Thiessen Polygons contained within the network of gaging stations.
flashboard	- A temporary barrier, of relatively low height and usually constructed of horizontal wooden planks, placed along the crest of a dam to prevent inflow into combined sewers due to high river levels.
gravity sewer	- A sewer in which the wastewater runs on descending gradients from source to outlet, and where no pumping is required.
hardware	- The physical equipment and devices which comprise a computer or computer system component.
in-system storage	- Unfilled, enclosed volumes within a sewer system capable of accepting and retaining wastewater for a period of time.
interceptor	- A sewer that receives dry weather flow from a number of tranverse sewers and additional predetermined quantities of storm water and conducts such waters to a point of treatment.
interface	- A common boundary between parts of a computer system.
milligrams per liter (mg/l)	- A unit of concentration of wastewater constituent. It is 0.001 gram in 1 liter of water.
million gallons per day (MGD)	- A unit of measure of the rate of liquid flow past a given point equal to one million gallons in one day.
outfall	- The point, location, or structure where wastewater or drainage discharges from a sewer.
pollutional load	- The quantity of material in a waste stream that requires treatment or exerts an adverse effect on the receiving stream.

regulator	- A device for regulating the flow into an interceptor from a combined sewer.
sanitary wastewater	- Domestic wastewater with storm and surface water excluded.
sluice gate	- A vertically sliding gate of any shape used to control or shut off flow to a sewer or in a sewer.
software	- The programs or instructions which control the hardware to perform some computer operation.
sewer system	- Collectively, all of the property involved in the operation of a sewer utility. It includes land, wastewater lines and appurtenances, pumping stations, treatment works and general property. Also referred to as a sewerage system or wastewater collection system.
storm wastewater	- That portion of liquid, resulting from precipitation runoff, flowing in combined sewers, during or after a period of rainfall.
Thiessen polygon	- A device for determining the zone within which data taken at a rain gage station are applicable in a network of gaging stations.
translatory wave	- A moving or advancing wave or series of waves that tend to overtake each other and form a single larger wave. It is caused by any sudden change in conditions of flow.
uncontrolled storage	- Storage not controlled by any remotely operated gates but depending entirely on weir or river elevations.
wastewater	- The spent water of a community. It may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants and institutions together with any storm water that may be present.
watershed	- The divide between drainage basins.

SECTION XV
APPENDICES

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A. GRAB SAMPLING PROGRAM RESULTS

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APPENDIX A

TABLE 1

Average of Daily Grab Samples - 1968

Sewer Location	Susp. Sol. mg/l	BOD mg/l	Tot.P mg/l	Phenols ug/l	Oil & Grease mg/l
Pembroke	195	111	14.8	78	34
Frisbee E.S.	194	90	10.2	79	32
Frisbee W.S.	192	148	16.1	104	70
7 Mile E.S.	532	458	15.0	177	75
7 Mile W.S.	790	267	16.8	151	83
McNichols	180	158	11.2	117	95
Puritan E.S.	332	181	18.2	163	58
Puritan W.S.	335	234	16.6	144	86
Fenkell-Lyndon	423	184	15.4	137	49
Schoolcraft	180	192	16.3	214	48
Glendale	482	113	11.4	81	67
Plymouth	592	298	16.3	89	230
W. Chicago	1350	197	15.9	89	100
Joy Road	915	202	16.4	111	100
Tireman	387	149	15.3	195	26
Hubbell-Southfield	78	43	3.1	75	22
Dearborn (Miller Rd.)	270	144	7.4	9700	55
Baby Creek	502	227	7.9	2775	2775
Flora	238	162	8.3	235	1395
Carbon	452	109	11.3	200	62
Pulaski	817	181	10.4	276	140
Dearborn Avenue	733	222	10.6	129	77
Schroeder	223	97	10.5	193	116
Dragoon	702	203	4.3	236	20
Campbell	185	107	8.0	348	122
Morrell	166	125	4.3	109	65
Ferdinand	146	111	8.8	144	84
Summitt	327	183	4.4	238	82
Scotten	195	95	4.7	145	443

APPENDIX A

TABLE 1
(Continued)

Sewer Location	Susp. Sol. mg/1	BOD mg/1	Tot.P mg/1	Phenols ug/1	Oils & Grease mg/1
McKinstry	203	92	5.4	183	177
Swain	69	21	4.7	227	11
W. Gd. Blvd.	117	88	5.1	60	25
24th	149	217	6.9	78	104
21st	498	270	7.5	113	858
18th	648	390	7.0	125	99
12th	387	208	4.4	98	116
11th	92	116	5.9	58	14
3rd	239	174	4.9	111	163
First-Hamilton	140	186	2.7	39	31
Woodward	155	38	2.9	110	38
Brush-Bates	342	221	3.6	136	84
St. Antoine	53	120	3.1	81	23
Hastings	180	90	7.1	147	52
Rivard	342	201	5.4	115	39
Riopelle	142	68	4.1	98	36
Orleans	1005	723	12.7	87	301
St. Aubin	335	299	8.6	76	127
Dubois	234	305	5.9	220	66
Chene	336	233	8.8	185	408
Adair	333	233	8.0	223	60
Leib	165	109	5.8	190	25
Mt. Elliott	232	208	6.6	166	71
Helen	209	170	9.5	164	45
Iroquois	182	108	6.9	156	34
McClellan	220	148	6.3	169	51
Conner	348	84	2.7	278	123
Ashland	327	156	6.1	220	40
Manistique	384	146	8.8	613	52
Fox Creek	411	204	6.7	232	88

APPENDIX A

TABLE 2

Average of Daily Grab Samples - 1969

Sewer Location	Susp. Sol. mg/1	BOD mg/1	Tot.P mg/1	Phenols ug/1	Oil & Grease mg/1
Pembroke	149	198	13.3	130	57
Frisbee E.S.	105	192	12.9	222	53
Frisbee W.S.	117	120	9.6	180	29
7 Mile E.S.	172	80	11.4	212	14
7 Mile W.S.	70	211	11.4	326	60
McNichols	115	98	6.8	163	24
Puritan E.S.	85	110	11.5	212	19
Puritan W.S.	253	99	10.6	218	19
Fenkell-Lyndon	411	134	13.6	239	31
Schoolcraft	302	104	15.0	286	26
Glendale	399	64	12.5	159	28
Plymouth	200	260	17.3	247	42
W. Chicago	163	111	9.0	239	25
Joy Road	147	107	13.5	148	24
Tireman	170	122	15.4	149	19
Hubbell-Southfield	78	43	3.1	75	19
Dearborn (Miller Rd.)	402	166	8.3	1250	64
Baby Creek	446	109	7.6	963	121
Flora	294	52	6.8	257	182
Carbon	309	110	8.5	214	34
Pulaski	453	528	7.3	99	689
Dearborn Avenue	115	230	9.3	249	41
Schroeder	239	251	7.5	269	81
Dragoon	625	246	8.0	142	680
Campbell	205	151	7.8	165	87
Morrell	197	154	5.9	181	74
Ferdinand	213	259	8.2	109	550
Summitt	163	205	3.1	152	89
Scotten	204	29	8.8	125	29

APPENDIX A

TABLE 2
(Continued)

Sewer Location	Susp. Sol. mg/l	BOD mg/l	Tot.P mg/l	Phenols ug/l	Oils & Grease mg/l
McKinstry	471	213	6.5	199	188
Swain	189	84	3.2	329	23
W. Gd. Blvd.	210	128	6.4	191	44
24th	169	86	4.8	179	91
21st	271	210	5.0	131	162
18th	762	328	6.1	188	132
12th	80	24	2.0	81	13
11th	227	139	8.5	49	38
3rd	422	152	4.3	107	157
First-Hamilton	184	76	3.7	18	45
Woodward	413	103	4.6	122	65
Brush-Bates	225	206	3.1	115	33
St. Antoine	119	49	3.5	73	14
Hastings	218	163	5.4	206	57
Rivard	142	124	5.2	120	21
Riopelle	224	169	8.2	243	133
Orleans	1005	730	11.9	70	240
St. Aubin	729	424	10.5	112	73
Dubois	267	350	6.7	265	81
Chene	338	233	8.9	185	409
Adair	460	226	7.0	236	91
Leib	148	109	5.8	173	25
Mt. Elliott	229	157	7.6	179	44
Helen	268	157	11.5	105	51
Iroquois	240	199	8.1	96	55
McClellan	268	198	9.1	95	35
Conner	248	84	3.7	322	43
Ashland	257	195	5.8	146	27
Manistique	101	111	4.0	130	22
Fox Creek	228	146	4.8	228	26

APPENDIX A

TABLE 3

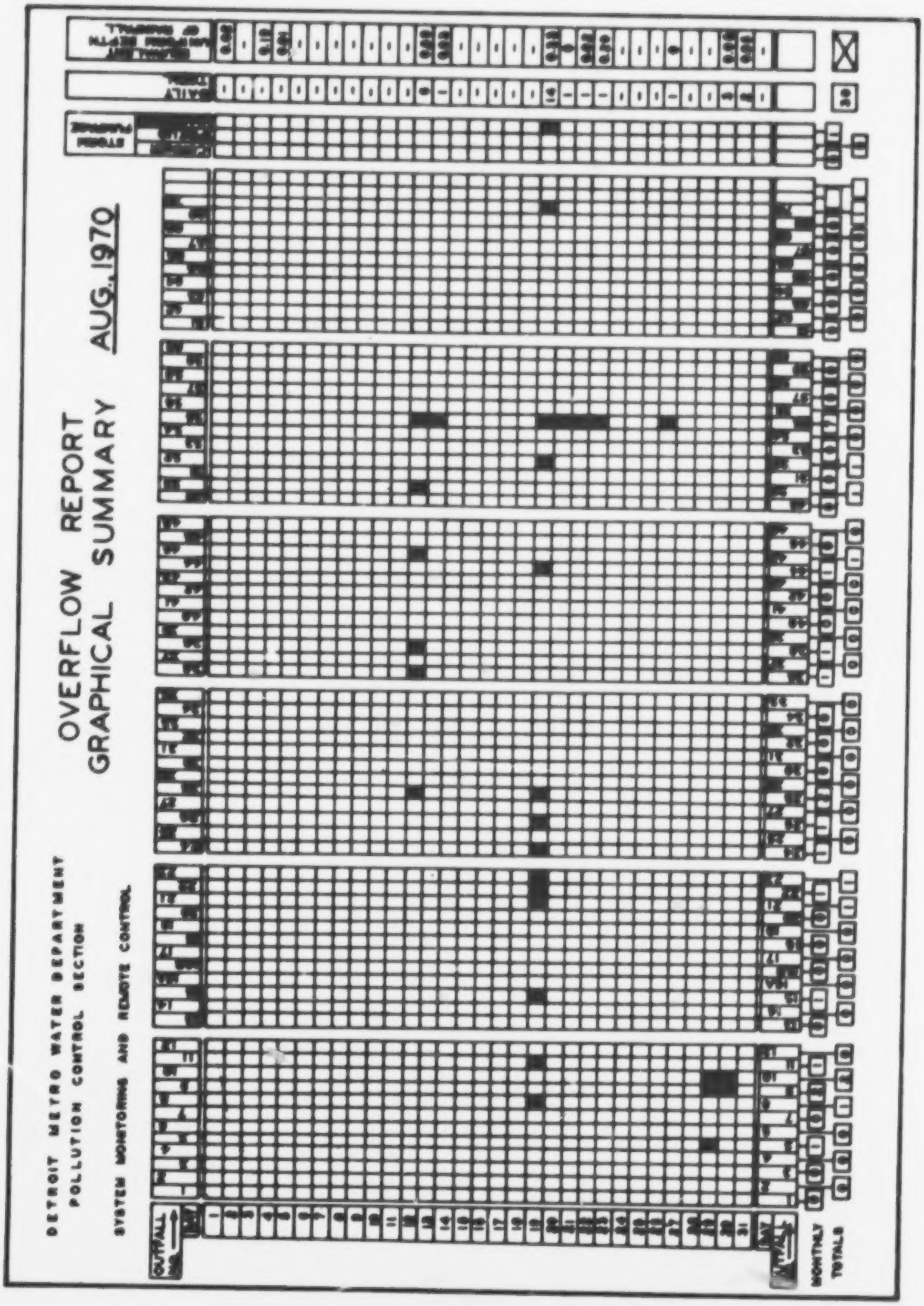
Average of Daily Grab Samples - 1970

Sewer Location	Susp. Sol. mg/1	BOD mg/1	Tot.P mg/1	Phenols ug/1	Oil & Grease mg/1
Pembroke	169	293	13.7	108	48
Frisbee E.S.	278	225	8.0	78	296
Frisbee W.S.	307	269	13.0	156	48
7 Mile E.S.	746	268	10.6	88	32
7 Mile W.S.	5069	382	25.8	155	113
McNichols	707	184	10.4	234	112
Puritan E.S.	168	183	18.2	99	177
Puritan W.S.	238	157	14.2	230	53
Fenkell-Lyndon	256	259	15.5	120	51
Schoolcraft	435	292	20.4	218	63
Glendale	4294	348	38.0	60	176
Plymouth	1453	211	48.2	155	184
W. Chicago	318	260	----	---	116
Joy Road	25,789	270	----	---	543
Tireman	348	293	----	---	81
Hubbell-Southfield	2384	302	17.0	460	253
Dearborn (Miller Rd.)	342	174	9.9	1358	179
Baby Creek	152	156	5.6	1500	553
Flora	217	154	6.2	160	65
Carbon	1101	230	11.5	490	407
Pulaski	408	233	8.6	98	185
Dearborn Avenue	83	168	2.3	68	58
Schroeder	285	183	7.3	100	112
Dragoon	359	187	8.1	279	81
Campbell	138	140	6.7	134	99
Morrell	104	152	5.2	224	55
Ferdinand	410	99	8.9	170	136
Summitt	6115	272	17.6	320	428
Scotten	72	75	3.0	195	25

APPENDIX A

TABLE 3
(Continued)

Sewer Location	Susp. Sol. mg/l	BOD mg/l	Tot.P mg/l	Phenols ug/l	Oils & Grease mg/l
McKinstry	465	238	7.2	189	173
Swain	53	127	1.5	360	20
W. Gd. Blvd.	162	102	4.1	278	36
24th	181	120	4.5	442	25
21st	177	166	4.5	117	33
18th	528	317	5.1	250	81
12th	289	235	5.7	215	160
11th	143	167	8.3	185	31
3rd	213	237	4.0	131	42
First-Hamilton	69	187	4.6	124	31
Woodward	256	229	4.3	410	78
Brush-Bates	382	259	4.6	269	72
St. Antoine	29	79	4.0	161	30
Hastings	188	237	4.0	169	82
Rivard	595	394	4.6	172	68
Riopelle	234	354	8.4	154	98
Orleans	1006	727	8.8	161	229
St Aubin	607	541	6.9	179	94
Dubois	322	465	6.1	132	73
Chene	367	258	15.7	258	142
Adair	382	269	10.8	199	61
Leib	---	---	---	---	--
Mt. Elliott	---	---	---	---	--
Helen	399	327	13.9	370	87
Iroquois	241	279	9.8	269	75
McClellan	133	127	7.4	141	37
Conner	---	---	---	---	--
Ashland	109	138	9.8	214	33
Manistique	156	163	8.6	605	25
Fox Creek	103	118	8.0	146	62


DETROIT METRO WATER DEPARTMENT
POLLUTION CONTROL SECTION
SYSTEM MONITORING AND REMOTE CONTROL
OVERFLOW REPORT
GRAPHICAL SUMMARY
AUG. 1970
OUTFALL NO.
DAY
MONTHLY TOTALS

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        SYSTEM MONITORING                                   DETROIT METRO WATER DEPT.
        AND REMOTE CONTROL                                  POLLUTION CONTROL SECTION

                               OVERFLOW REPORT
                               ======== ======                   PAGE 1

                             AUGUST 1970

   DATE  OVER- SEN. TYPE     SEWER        NO.     SEWER    OVERFLOW            REMARKS
         FLOWS      SEN.  DESIGNATION    BBLS.    SIZE     DURATION

08-01-70   0                                                         RAIN. EQUIV UNIFORM DEPTH 0.02"
                                                                     B-39 (JUNCTION) TRANSMITTER TO
                                                                     BE CHECKED.  GATE CHATTER

08-02-70   0

08-03-70   0                                                         RAIN CELLS. E.U.D.   0.19"
                                                                     SENSOR CHATTER AR B-22 (WOOD
                                                                     WARD) DUE TO TRANSMITTER.  RAIN
                                                                     CELL CONTAINED WITHIN SYSTEM

08-04-70   0                                                         RAIN CELL. E.U.D.   0.01"

08-05-70   0

08-06-70   0

08-07-70   0

08-08-70   0

08-09-70   0

08-10-70   0

08-11-70   0

08-12-70       B-28  E       VERMONT        2       4-3        0.30 RAIN CELLS. E.U.D. = 0.69"

        E = ELECTRODES ON DAMS          P = PROXIMITY SWITCH ON BACKWATER GATES
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           SYSTEM MONITORING
           AND REMOTE CONTROL                                       DETROIT METRO WATER DEPT.
                                                                    POLLUTION CONTROL SECTION
                                        OVERFLOW REPORT
                                        ======== ======                   PAGE 2

                                     AUGUST 1970

    DATE   OVER- SEN.  TYPE        SEWER           NO.     SEWER      OVERFLOW              REMARKS
           FLOWS       SEN.     DESIGNATION       BBLS.     SIZE      DURATION
                 B-36   P          CLARK            3    8-8 X 7-6      0.32
                 B-38   P         MORRELL           1       9-0         0.22
                 B-45   P         DEARBORN          1       5-9         0.07
                 B-50   P        BABY CREEK         2   14-6 X 17-6     2.48
             6   B-55   E   W.CHI(W OF ROUGE)       1       4-6         1.20

  08-13-70   1   B-55   E   W.CHI(W OF ROUGE)       1       4-6         1.10 RAIN CELLS, E.U.D. = 0.03"
                                                                             B-66(GLENHURST) SIGNAL PROB

  08-14-70   0

  08-15-70   0

  08-16-70   0

  08-17-70   0

  08-18-70   0

  08-19-70
                 B-08   E          HELEN            1       9-0         1.03 E.U.D. = 0.33"
                 B-11   P          ADAIR            1       5-0         0.25 GATE CHATTER
                 B-15   E        ST. AUBIN          1    3-6 X 4-8      0.10
                 B-21   P      BATES(BRUSH)         3    8-6 X 6-4      5.77
                 B-22   E        WOODWARD           1    8-0 / 9-0      2.20
                 B-23   P        GRISWOLD           2       7-0         6.38
                 B-24   P      FIRST-HAMILTON       2   10-0 X 10-6     5.45
                 B-26   E       ELEVENTH ST.        2       5-0         0.45
                 B-28   E         VERMONT           2       4-3         0.58

           E = ELECTRODES ON DAMS            P = PROXIMITY SWITCH ON BACKWATER GATES
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      SYSTEM MONITORING                                      DETROIT METRO WATER DEPT.
      AND REMOTE CONTROL                                     POLLUTION CONTROL SECTION

                                   OVERFLOW REPORT
                                   ======== ======              PAGE 3

                                     AUGUST 1970

  DATE    OVER- SEN. TYPE       SEWER          NO.     SEWER     OVERFLOW           REMARKS
          FLOWS      SEN.    DESIGNATION      BBLS.     SIZE     DURATION
                B-44  E         CARY            1     3-4 X 5-3    0.25
                B-52  P        WARREN           1        7-6       0.63
                B-55  E  W.CHI(W OF ROUGE)      1        4-6       1.75
                B-70  E       PEMBROKE          1       13-0       0.00 ELECTRODE FOULED TIME UNKNOWN
            14  P.S.      OAKWOOD PUMP STA                         0.00 2,070,000 GALLONS

08-20-70     1  B-55  E  W.CHI(W OF ROUGE)      1        4-6       1.80 NO RAIN INDICATED

08-21-70     1  B-55  E  W.CHI(W OF ROUGE)      1        4-6       0.68 0.02 IN RAIN AT R-14

08-22-70     1  B-55  E  W.CHI(W OF ROUGE)      1        4-6       2.43 E.U.D.   0.20 DURATION 5 HOURS
                                                                        RAINFALL ALMOST COMPLETELY CON
                                                                        TAINED DUE TO LOW INTENSITY

08-23-70     0

08-24-70     0

08-25-70     0

08-26-70     1  B-55  E  W.CHI(W OF ROUGE)      1        4-6       2.00 NO RAIN INDICATED. TRANSMITTER

08-27-70     0                                                          AND ELECTRODE TO BE CHECKED

08-28-70     0

08-29-70        B-05  E      MC CLELLAN         1        6-5       0.83 E.U.D.   0.08 (RAIN CELLS)
                B-09  E      MT.ELLIOT          4        5-0       2.22

      E = ELECTRODES ON DAMS          P = PROXIMITY SWITCH ON BACKWATER GATES
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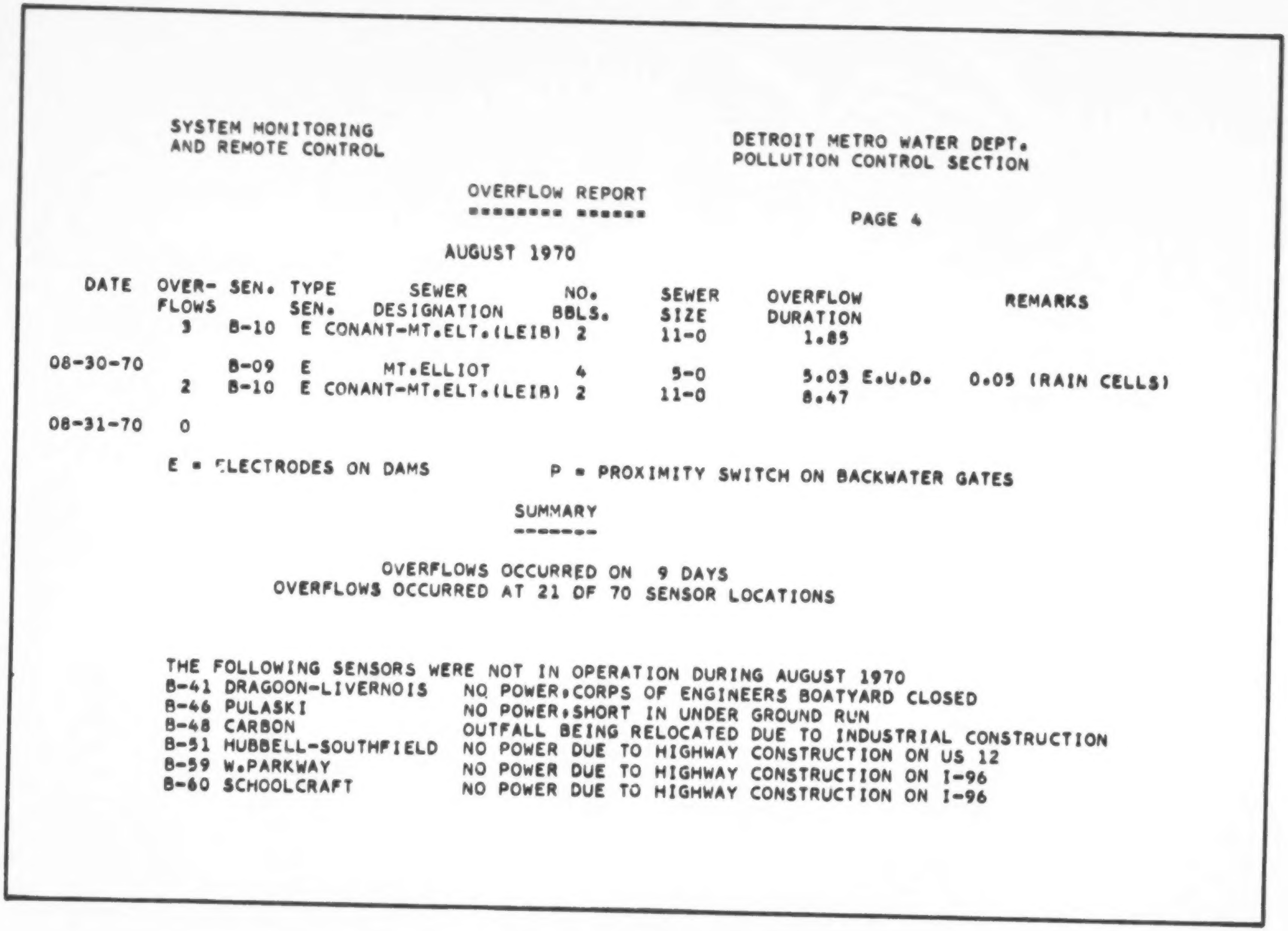

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SYSTEM MONITORING
AND REMOTE CONTROL                                      DETROIT METRO WATER DEPT.
                                                        POLLUTION CONTROL SECTION
                                  OVERFLOW REPORT
                                  ======== ======             PAGE 4

                             AUGUST 1970

   DATE  OVER- SEN. TYPE      SEWER        NO.     SEWER    OVERFLOW            REMARKS
         FLOWS      SEN.   DESIGNATION    BBLS.    SIZE     DURATION
           3   B-10  E CONANT-MT.ELT.(LEIB) 2      11-0       1.85

08-30-70       B-09  E       MT.ELLIOT      4       5-0         5.03 E.U.D.   0.05 (RAIN CELLS)
           2   B-10  E CONANT-MT.ELT.(LEIB) 2      11-0         8.47

08-31-70   0

        E = ELECTRODES ON DAMS          P = PROXIMITY SWITCH ON BACKWATER GATES

                                    SUMMARY
                                    -------

                         OVERFLOWS OCCURRED ON  9 DAYS
                   OVERFLOWS OCCURRED AT 21 OF 70 SENSOR LOCATIONS


        THE FOLLOWING SENSORS WERE NOT IN OPERATION DURING AUGUST 1970
        B-41 DRAGOON-LIVERNOIS    NO POWER,CORPS OF ENGINEERS BOATYARD CLOSED
        B-46 PULASKI              NO POWER,SHORT IN UNDER GROUND RUN
        B-48 CARBON               OUTFALL BEING RELOCATED DUE TO INDUSTRIAL CONSTRUCTION
        B-51 HUBBELL-SOUTHFIELD   NO POWER DUE TO HIGHWAY CONSTRUCTION ON US 12
        B-59 W.PARKWAY            NO POWER DUE TO HIGHWAY CONSTRUCTION ON I-96
        B-60 SCHOOLCRAFT          NO POWER DUE TO HIGHWAY CONSTRUCTION ON I-96
        SYSTEM MONITORING                                                    DETROIT METRO WATER DEPT.
        AND REMOTE CONTROL                                                   POLLUTION CONTROL SECTION

                                  EQUIVALENT UNIFORM DEPTH OF RAINFALL
                                        (THEISSEN POLYGON METHOD)
                                                                                   PAGE 1
                                      08-01-70 THROUGH 08-01-70

I======I=============I=============I=============I=============I=============I=============I=============I
I      I   SUNDAY    I   MONDAY    I   TUESDAY   I  WEDNESDAY  I  THURSDAY   I   FRIDAY    I  SATURDAY   I
I      I             I             I             I             I             I             I  08-01-70   I
I GAGE I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I
I======I=============I=============I=============I=============I=============I=============I=============I
I R-01 I             I             I             I             I             I             I 0.01   0.10 I
I R-02 I             I             I             I             I             I             I 0.00   0.00 I
I R-03 I             I             I             I             I             I             I 0.02   0.46 I
I R-04 I             I             I             I             I             I             I 0.03   0.49 I
I R-05 I             I             I             I             I             I             I 0.01   0.13 I
I R-06 I             I             I             I             I             I             I 0.09   0.83 I
I R-11 I             I             I             I             I             I             I 0.02   0.30 I
I R-12 I             I             I             I             I             I             I 0.01   0.17 I
I R-13 I             I             I             I             I             I             I 0.01   0.14 I
I R-14 I             I             I             I             I             I             I 0.03   0.47 I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 1.I             I             I             I             I             I             I    3.13     I
IROW 2.I             I             I             I             I             I             I  147.40     I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 3.I             I             I             I             I             I             I    0.02     I
I======I=============I=============I=============I=============I=============I=============I=============I

                                        * SEE NOTE 1 ON LAST PAGE
                                        N SEE NOTE 2 ON LAST PAGE

     ROW 1. = SUM OF R X A
     ROW 2. = SUM OF A
     ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL
     SYSTEM MONITORING                                              DETROIT METRO WATER DEPT.
     AND REMOTE CONTROL                                             POLLUTION CONTROL SECTION

                              EQUIVALENT UNIFORM DEPTH OF RAINFALL
                                 (THEISSEN POLYGON METHOD)
                                                                        PAGE 2
                                  08-02-70 THROUGH 08-08-70

I======I==============I==============I==============I==============I==============I==============I==============I
I      I    SUNDAY    I    MONDAY    I   TUESDAY    I  WEDNESDAY   I   THURSDAY   I    FRIDAY    I   SATURDAY   I
I      I   08-02-70   I   08-03-70   I   08-04-70   I   08-05-70   I   08-06-70   I   08-07-70   I   08-08-70   I
I GAGE I R       R X AI R       R X AI R       R X AI R       R X AI R       R X AI R       R X AI R       R X AI
I======I==============I==============I==============I==============I==============I==============I==============I
I R-01 I 0.00     0.00I 0.15     1.51I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-02 I 0.00     0.00I 0.00N    0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-03 I 0.00     0.00I 0.00N    0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-04 I 0.00     0.00I 0.00N    0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-05 I 0.00     0.00I 0.00N    0.00I 0.01     0.13I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-06 I 0.00     0.00I 0.00N    0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-11 I 0.00     0.00I 0.07N    1.06I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-12 I 0.00     0.00I 0.00N    0.00I 0.08     1.41I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-13 I 0.00     0.00I 0.23     3.36I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I R-14 I 0.00     0.00I 0.00N    0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I 0.00     0.00I
I======I==============I==============I==============I==============I==============I==============I==============I
IROW 1.I     0.00     I     4.87     I     1.55     I     0.00     I     0.00     I     0.00     I     0.00     I
IROW 2.I    147.40    I    24.71     I    147.40    I    147.40    I    147.40    I    147.40    I    147.40    I
I======I==============I==============I==============I==============I==============I==============I==============I
IROW 3.I     0.00     I     0.19     I     0.01     I     0.00     I     0.00     I     0.00     I     0.00     I
I======I==============I==============I==============I==============I==============I==============I==============I

                                  * SEE NOTE 1 ON LAST PAGE
                                  N SEE NOTE 2 ON LAST PAGE

  ROW 1. = SUM OF R X A
  ROW 2. = SUM OF A
  ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL
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SYSTEM MONITORING
AND REMOTE CONTROL

DETROIT METRO WATER DEPT.
POLLUTION CONTROL SECTION

EQUIVALENT UNIFORM DEPTH OF RAINFALL
(THEISSEN POLYGON METHOD)

PAGE 3

08-09-70 THROUGH 08-15-70

GAGE	SUNDAY 08-09-70 R	SUNDAY 08-09-70 R X A	MONDAY 08-10-70 R	MONDAY 08-10-70 R X A	TUESDAY 08-11-7 R	TUESDAY 08-11-7 R X A	WEDNESDAY 08-12-70 R	WEDNESDAY 08-12-70 R X A	THURSDAY 08-13-70 R	THURSDAY 08-13-70 R X A	FRIDAY 08-14-70 R	FRIDAY 08-14-70 R X A	SATURDAY 08-15-70 R	SATURDAY 08-15-70 R X A
R-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.06	0.60	0.00	0.00	0.00	0.00
R-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.00N	0.00	0.00	0.00	0.00	0.00
R-03	0.00	0.00	0.00	0.00	0.00	0.00	0.04N	0.93	0.00N	0.00	0.00	0.00	0.00	0.00
R-04	0.00	0.00	0.00	0.00	0.00	0.00	0.21	3.48	0.00N	0.00	0.00	0.00	0.00	0.00
R-05	0.01	0.13	0.00	0.00	0.00	0.00	1.30	17.29	0.00N	0.00	0.00	0.00	0.00	0.00
R-06	0.00	0.00	0.00	0.00	0.00	0.00	0.01N	0.09	0.00N	0.00	0.00	0.00	0.00	0.00
R-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.00N	0.00	0.00	0.00	0.00	0.00
R-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.00N	0.00	0.00	0.00	0.00	0.00
R-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.02	0.29	0.00	0.00	0.00	0.00
R-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00N	0.00	0.00N	0.00	0.00	0.00	0.00	0.00
ROW 1.	0.13		0.00		0.00		20.77		0.89		0.00		0.00	
ROW 2.	147.40		147.40		147.40		29.90		24.71		147.40		147.40	
ROW 3.	0.00		0.00		0.00		0.69		0.03		0.00		0.00	

* SEE NOTE 1 ON LAST PAGE
N SEE NOTE 2 ON LAST PAGE

ROW 1. = SUM OF R X A
ROW 2. = SUM OF A
ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL

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SYSTEM MONITORING
AND REMOTE CONTROL                                            DETROIT METRO WATER DEPT.
                                                              POLLUTION CONTROL SECTION
                           EQUIVALENT UNIFORM DEPTH OF RAINFALL
                                (THEISSEN POLYGON METHOD)
                                                                 PAGE 4
                             08-16-70 THROUGH 08-22-70

I======I=============I=============I=============I=============I=============I=============I=============I
I      I   SUNDAY    I   MONDAY    I   TUESDAY   I  WEDNESDAY  I  THURSDAY   I   FRIDAY    I  SATURDAY   I
I      I  08-16-70   I  08-17-70   I  08-18-70   I  08-19-70   I  08-20-70   I  08-21-70   I  08-22-70   I
I GAGE I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I
I======I=============I=============I=============I=============I=============I=============I=============I
I R-01 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.21   2.12 I 0.00   0.00 I 0.00   0.00 I 0.20   2.02 I
I R-02 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00*  0.00 I 0.00   0.00 I 0.00   0.00 I 0.18   2.06 I
I R-03 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.48  11.21 I 0.00   0.00 I 0.02   0.46 I 0.20   4.67 I
I R-04 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.45   7.47 I 0.00   0.00 I 0.00   0.00 I 0.24   3.98 I
I R-05 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.43   5.71 I 0.00   0.00 I 0.00   0.00 I 0.22   2.92 I
I R-06 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.71   6.59 I 0.00   0.00 I 0.00   0.00 I 0.18   1.67 I
I R-11 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.34   5.16 I 0.00   0.00 I 0.00   0.00 I 0.22   3.34 I
I R-12 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.12   2.12 I 0.00   0.00 I 0.00   0.00 I 0.19   3.36 I
I R-13 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.08   1.16 I 0.00   0.00 I 0.00   0.00 I 0.18   2.62 I
I R-14 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.21   3.31 I 0.00   0.00 I 0.02   0.31 I 0.25   3.94 I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 1.I    0.00     I    0.00     I    0.00     I   44.89     I    0.00     I    0.78     I   30.61     I
IROW 2.I  147.40     I  147.40     I  147.40     I  135.94     I  147.40     I  147.40     I  147.40     I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 3.I    0.00     I    0.00     I    0.00     I    0.33     I    0.00     I    0.00     I    0.20     I
I======I=============I=============I=============I=============I=============I=============I=============I

                                * SEE NOTE 1 ON LAST PAGE
                                N SEE NOTE 2 ON LAST PAGE

   ROW 1. = SUM OF R X A
   ROW 2. = SUM OF A
   ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL
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     SYSTEM MONITORING                                                          DETROIT METRO WATER DEPT.
     AND REMOTE CONTROL                                                         POLLUTION CONTROL SECTION

                                     EQUIVALENT UNIFORM DEPTH OF RAINFALL
                                          (THEISSEN POLYGON METHOD)
                                                                                       PAGE 5
                                         08-23-70 THROUGH 08-29-70

I======I=============I=============I=============I=============I=============I=============I=============I
I      I   SUNDAY    I   MONDAY    I   TUESDAY   I  WEDNESDAY  I   THURSDAY  I   FRIDAY    I  SATURDAY   I
I      I  08-23-70   I  08-24-70   I  08-25-70   I  08-26-70   I  08-27-70   I  08-28-70   I  08-29-70   I
I GAGE I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I
I======I=============I=============I=============I=============I=============I=============I=============I
I R-01 I 0.01   0.10 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.13   1.31 I
I R-02 I 0.01   0.11 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-03 I 0.01   0.23 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-04 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-05 I 0.01   0.13 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-06 I 0.01   0.09 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-11 I 0.01   0.15 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-12 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I R-13 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.05   0.73 I
I R-14 I 0.01   0.15 I 0.01   0.15 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00   0.00 I 0.00N  0.00 I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 1.I     0.98    I     0.15    I     0.00    I     0.00    I     0.00    I     0.00    I     2.04    I
IROW 2.I   147.40    I   147.40    I   147.40    I   147.40    I   147.40    I   147.40    I    24.71    I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 3.I     0.00    I     0.00    I     0.00    I     0.00    I     0.00    I     0.00    I     0.08    I
I======I=============I=============I=============I=============I=============I=============I=============I

                                       * SEE NOTE 1 ON LAST PAGE
                                       N SEE NOTE 2 ON LAST PAGE

  ROW 1. = SUM OF R X A
  ROW 2. = SUM OF A
  ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL
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SYSTEM MONITORING
AND REMOTE CONTROL                                              DETROIT METRO WATER DEPT.
                                                                POLLUTION CONTROL SECTION
                          EQUIVALENT UNIFORM DEPTH OF RAINFALL
                                (THEISSEN POLYGON METHOD)

                              08-30-70 THROUGH 08-31-70                PAGE 6

I======I=============I=============I=============I=============I=============I=============I=============I
I      I    SUNDAY   I    MONDAY   I   TUESDAY   I  WEDNESDAY  I  THURSDAY   I   FRIDAY    I  SATURDAY   I
I      I  08-30-70   I  08-31-70   I             I             I             I             I             I
I GAGE I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I R     R X A I
I======I=============I=============I=============I=============I=============I=============I=============I
I R-01 I 0.03   0.30 I 0.00   0.00 I             I             I             I             I             I
I R-02 I 0.00   0.00 I 0.00   0.00 I             I             I             I             I             I
I R-03 I 0.13   3.03 I 0.00   0.00 I             I             I             I             I             I
I R-04 I 0.00N  0.00 I 0.00   0.00 I             I             I             I             I             I
I R-05 I 0.00N  0.00 I 0.00   0.00 I             I             I             I             I             I
I R-06 I 0.01   0.09 I 0.00   0.00 I             I             I             I             I             I
I R-11 I 0.02   0.30 I 0.00   0.00 I             I             I             I             I             I
I R-12 I 0.04   0.70 I 0.00   0.00 I             I             I             I             I             I
I R-13 I 0.00N  0.00 I 0.00   0.00 I             I             I             I             I             I
I R-14 I 0.00N  0.00 I 0.00   0.00 I             I             I             I             I             I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 1.I     4.44    I     0.00    I             I             I             I             I             I
IROW 2.I    87.13    I   147.40    I             I             I             I             I             I
I======I=============I=============I=============I=============I=============I=============I=============I
IROW 3.I     0.05    I     0.00    I             I             I             I             I             I
I======I=============I=============I=============I=============I=============I=============I=============I

                               * SEE NOTE 1 ON LAST PAGE
                               N SEE NOTE 2 ON LAST PAGE

   ROW 1. = SUM OF R X A
   ROW 2. = SUM OF A
   ROW 3. = EQUIVALENT UNIFORM DEPTH OF RAINFALL
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SYSTEM MONITORING                                     DETROIT METRO WATER DEPT.
AND REMOTE CONTROL                                    POLLUTION CONTROL SECTION

                                                               PAGE 7

      GAGE      AREA         LOCATION

      R-01      10.10     EAST SIDE STATION
      R-02      11.46     CONNERS STATION
      R-03      23.37     CENTRAL MAINTAINANCE BUILDING
      R-04      16.60     POLICE DEPT. WEST SIDE RADIO STATION
      R-05      13.30     SPRINGWELLS STATION
      R-06       9.29     OAKWOOD STATION
      R-11      15.19     NORTHWEST STATION
      R-12      17.72     NORTHERN YARD
      R-13      14.61     NORTHEAST STATION
      R-14      15.77     WEST YARD

      TOTAL DRAINAGE AREA = 147.40 SQUARE MILES

NOTE
   1.  * AFTER GAGE READING INDICATES RAIN GAGE IS OUT OF SERVICE OR READING IS QUESTIONABLE
   2.  N AFTER GAGE READING INDICATES RAIN GAGE IS NOT USED IN ANALYSIS OF ISOLATED STORM CELL

       FOR CASES 1 AND 2 ABOVE, THE CORRESPONDING POLYGON AREA IS ASSUMED = 0 IN ALL CALCULATIONS

   3.  A = AREA OF THEISSEN POLYGON IN SQUARE MILES
   4.  R = TOTAL RAINFALL RECORDED FOR A GIVEN DAY
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